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INDIVIDUALIZED SCIENCE INSTRUCTIONAL SYSTEM

FOSSIL FUELS

ANNOTATED TEACHER'S EDITION

Ginn and Company

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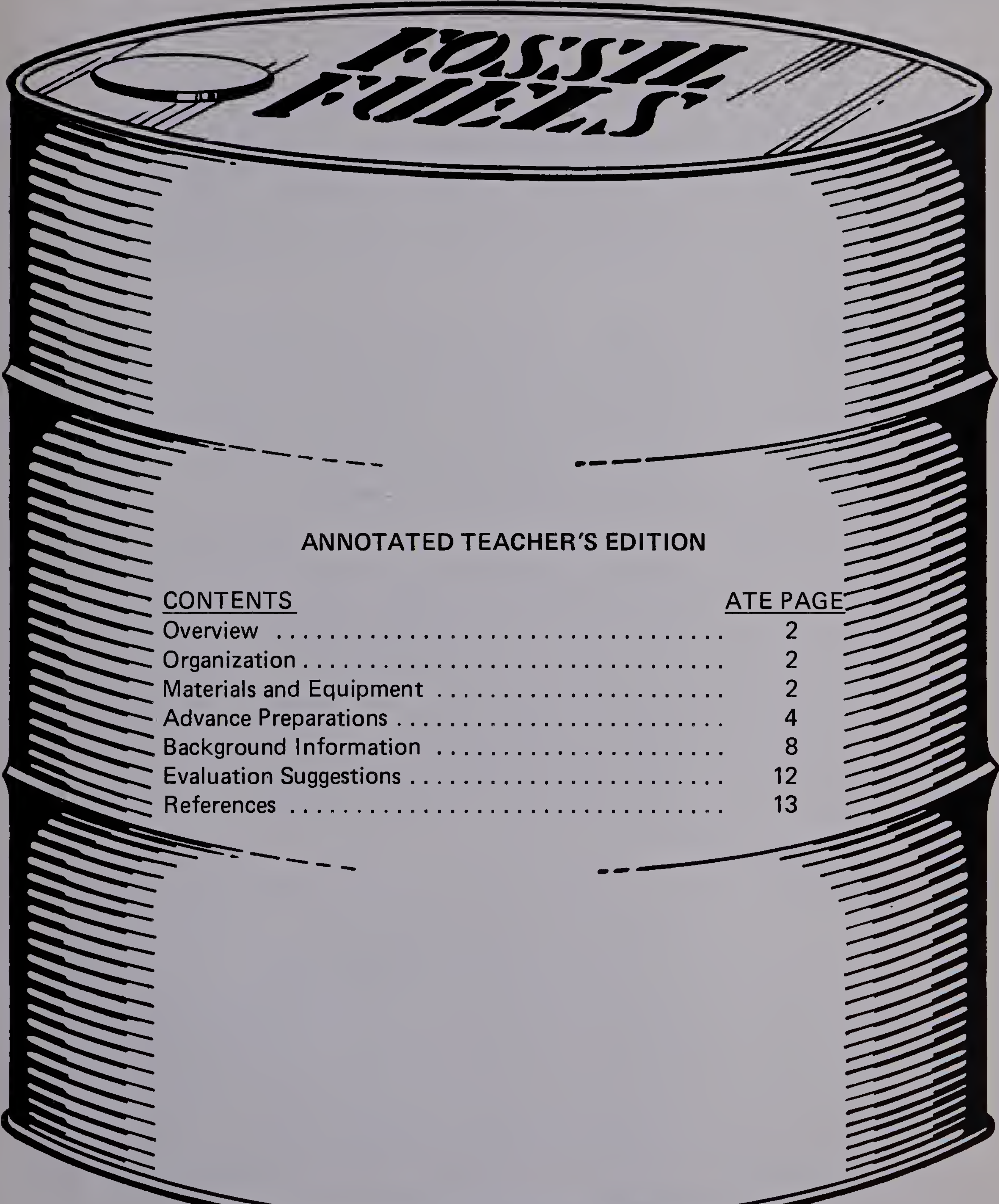

ANNOTATED TEACHER'S EDITION

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OVERVIEW

Fossil Fuels speaks realistically to the heart of the problem of the energy crisis. People must slow down the growing use of fossil fuels. This will buy time to develop alternate energy sources before fossil fuel resources are exhausted.

The minicourse deals with the origins of fossil fuels and the ways these fuels are processed and used. This discussion naturally leads to questions about pollution and pollution control.

As a result of studying *Fossil Fuels*, students should know more about the world's fossil fuel resources and be capable of making better informed decisions about their use.

ORGANIZATION

Fossil Fuels contains ten core activities, three advanced activities, and four excursion activities. The first activity in each section is a planning activity and should be done before any of the other activities in that section. Students who plan to do Activity 2 should do it first; those planning to do Activity 10 should do it as the last core activity. All other activities may be done in any order within their section.

Core activities focus on the finite sources of fossil fuels, environmental effects of obtaining fossil fuels, the refining of petroleum, the products and pollutants formed by burning fossil fuels, grades of gasoline, trends in United States and world consumption of fossil fuels, the conservation of energy law, and choices of which fuel to use.

The advanced activities deal with the unique ability of carbon to form a large variety of compounds and the fact that certain molecules (isomers) differ in properties while containing the same numbers and kinds of atoms.

The excursion activities deal with obtaining fuels from garbage and oil shale and with cleaning up oil spills.

MATERIALS AND EQUIPMENT

The following tables show the quantity and the frequency of use of each item used in each activity. The activities that require no materials are not listed in the tables.

It is important to collect and organize all the materials for each minicourse before the students begin any of the activities, since the students will be working simultaneously on different activities. Having all materials readily available allows students to do the activities in the order they choose. The amount of material you will need to make available will depend on the number of lab groups that will be doing each activity. As lab groups use the "skipping option" and as they scatter themselves throughout the activities, the total amount of materials needed at one time for each activity will decrease.

NONCONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP[†] PER ACTIVITY								
	3	4	7	9	12	13	15	16	17
Asbestos pad	1								1
Beaker, 100 ml, or baby-food jar		2							
Burner, Bunsen, or other heat source	1	1		1			1		1
Clamp, utility, for ring stand	1			2			1		1
Flask, Erlenmeyer, 250 ml		2		1					
Gauze, wire				1					
Graduated cylinder, 10 ml or 25 ml		1						1	
Graduated cylinder, 100 ml	1								
Grease pencil	1					1		1	
Leads, test, with alligator clips				3					
Milliammeter, DC				1					
*Model, molecular, set (optional)					1	1			
Mortar and pestle									1
*Pan, aluminum, rectangular								1	
Pencil		1							
Ring for ring stand				1					
Ring stand	1			2			1		1
Safety goggles	1	1		1		1	1	1	1
Spatula, narrow							1		1
Spoon, large								1	
Stirring rod	1						1		
*Stopper, #2, one hole, with glass tubing									1
Stopper, #2, solid								1	
*Stopper, #4, one hole, with glass tubing							1		
*Stopper, #4, two hole, with glass tubing and thermometer	1								
*Stopper, #5, one hole, with glass nozzle inserted				1					
Stopper, solid, to fit 250-ml flask		2							
Switch, knife				1					
Test tube, 13 mm X 100 mm (small)						2			
Test tube, 18 mm X 150 mm (medium)	3							1	*1
Test tube, 25 mm X 200 mm (large), heat resistant	1						*1		
Test-tube rack	1					1		1	
Tongs		1							1
Tubing, rubber (cm)	60								
*Turbine-generator apparatus:				1					
motor, small, electric, 1.5 volts				1					
lid, from 1-lb coffee can				1					
eraser, rubber, from pencil				1					
glue, strong (drop)				2					
*Wood strip, approximately 2 cm X 15 cm								1	
Resource Unit 2			1						
Resource Unit 5		1							
Resource Unit 14	1								
Resource Unit 17	1	1		1					1
Resource Unit 18				1					
Resource Unit 22		1							
Actions and Reactions					1				

*See "Advance Preparations."

[†] A *lab group* is defined as one student, a pair of students, or any size group of students that you choose.

CONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP† PER ACTIVITY						
	3	4	9	13	15	16	17
*Alcohol (ml)					10		
*Alcohol, isopropyl, 50%, in dropping bottle (ml)	15						
*Aluminum-foil square, 6 cm X 6 cm		1					
Boiling chip	1		1				
*Cloth square, cotton, 10 cm X 10 cm						1	
*Cobalt chloride test paper (strip)		2					
Detergent, household, squeeze bottle (ml)						3	
*Iron chloride, $FeCl_3$, 0.1M, in dropping bottle (drop)				50			
*Limewater, $Ca(OH)_2$, saturated solution, in dropping bottle (ml)		15					
Matches, safety	2	1	1		1		2
Oil, motor or fuel (ml)						10	
*Oil shale, small chunk							1
*Organic waste mixture (about ½ test tube) consisting of the following:					1		
fruit peel, citrus, DRIED, piece about 3 cm^2					1		
paper, waste, piece about 5 cm^2					1		
polyethylene, film, piece about 5 cm^2					1		
wood splint, small					1		
*Paper strip, 1 cm X 10 cm	4						
*Paper strip, 3 cm X 5 cm							1
Para-hydroxybenzoic acid (g)				0.05			
Salicylic acid (g)				0.05			
Steel-wool tuft							1
Straw, soda		1		2			
Tongue depressor						1	
Wood splint					3		1

*See "Advance Preparations."

†A *lab group* is defined as one student, a pair of students, or any size group of students that you choose.

ADVANCE PREPARATIONS

Activity 3

Bent glass tubing: Use a 10-cm length of tubing. Put a wing top (flame spreader) over the barrel of the Bunsen burner. Hold the ends of the glass tubing between your fingers, and rotate the tubing in the upper region of the flame until the middle is very soft and pliable. Remove the tubing from the flame, and quickly bend the tubing to form an angle of about 120°. Let the glass cool. Fire-polish the ends. Use glycerine or water as a lubricant when inserting the bent glass tubing and a thermometer (−10°C to 110°C) into the proper size rubber stopper.

Isopropyl alcohol: Make a 50% (by volume) solution mixing equal volumes of isopropyl alcohol and water.

Paper strips: Any scrap paper will do. Cut strips that are 1 cm X 10 cm, four per lab group.

Activity 4

Cobalt chloride paper: If commercially prepared strips of cobalt chloride paper are not available, you can prepare them yourself. Make 10 to 20 millilitres of a saturated solution of cobalt chloride crystals. Soak strips of filter paper in the saturated solution for ten minutes. Dry the strips by heating them about 100°C in a dish or an oven until they turn blue.

Limewater: Put 5 grams of calcium hydroxide into a 100-ml container. Add 1 litre of tap water. Stopper the container, and vigorously shake the contents. Let the container stand overnight. Any undissolved solid will settle to the bottom. The clear liquid above the solid is limewater. Carefully pour the clear liquid into supply bottles.

Aluminum foil: Cut 6 cm X 6 cm squares from heavy-duty aluminum foil or from aluminum frozen-food containers.

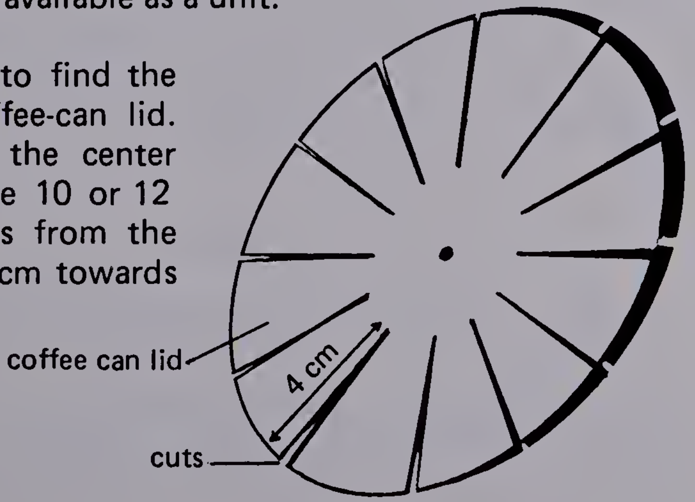
An alcohol burner could possibly be used in this activity, but remember that alcohol is not a fossil fuel. Also, it can produce lots of soot. An inexpensive candle is another possibility, since most inexpensive candle wax comes from petroleum. But soot is an even greater problem with candles.

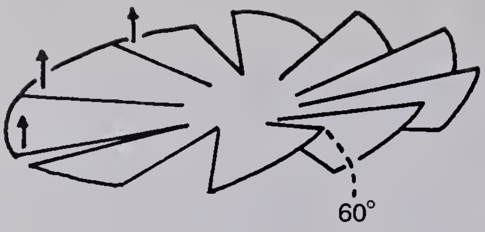
Activity 9

Glass nozzle: First bend a 20-cm piece of glass tubing at right angles 5 cm from one end, following the procedure described on page ATE 4 for Activity 3. Then repeat the procedure 5 cm from the other end, except this time gently pull the soft glass apart so that a nozzle shape is formed. Use a file to cut the glass. Fire-polish the ends. Insert the short end of the nozzle into the appropriate stopper.

Turbine-generator apparatus: Follow the steps below. Then keep the apparatus available as a unit.

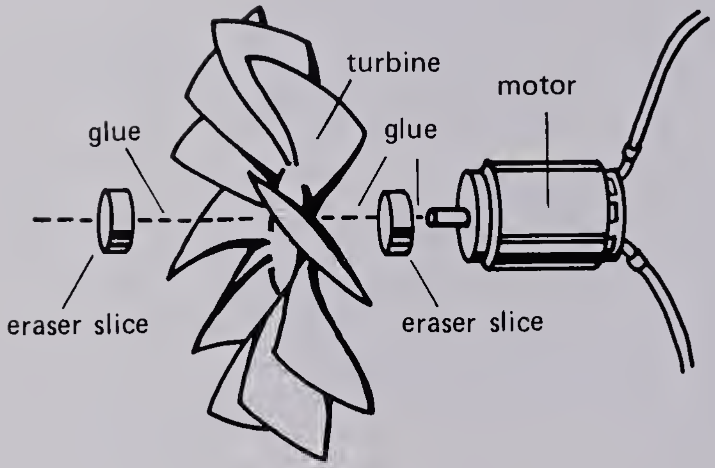
A. Use a compass to find the center of the coffee-can lid. Punch a hole in the center with a nail. Make 10 or 12 evenly spaced cuts from the edge, cutting in 4 cm towards the center.





B. Cut two slices 1 to 2 mm thick, from a pencil eraser. Use the compass to make a hole in the center of each eraser slice.

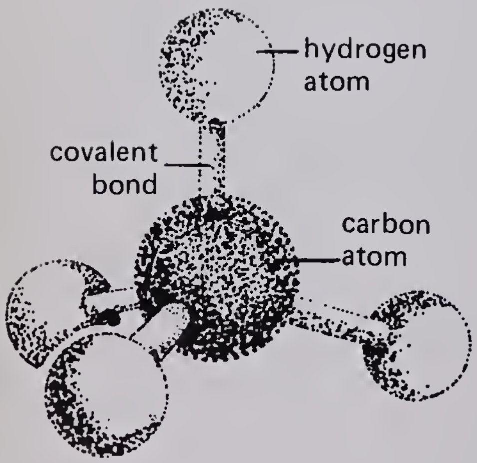
C. Glue one eraser slice on the center of one side of the lid, aligning the holes.



D. Form the blades of the turbine by twisting each segment of the lid 60° to 90°. Make sure all twists are parallel.

E. Push first the turbine onto the "generator" (motor) shaft, then the second eraser slice. Glue the turbine to the shaft. Make sure the turbine rotates freely.

Activity 12



Models: It would be helpful to have ball-and-stick models or other molecular models available for Activities 12 and 13. You may want to make a model of methane, CH_4, to show the tetrahedral shape of the molecule. An easy way to construct one is to take one large sphere (plastic foam, clay, etc.), four smaller spheres, and four connectors (pipe cleaners, toothpicks, etc.). Make a tripod to support the large ball with the three small balls as feet. Put the fourth small ball straight up on top. Then turn the tripod so it's on another set of feet. One small ball should again be straight up. If it isn't, adjust it. Repeat the process until, no matter how you set the model, the top ball is straight up.

Activity 13

Models: To make molecular models, see the above instructions for Activity 12.

Iron chloride, $FeCl_3$, 0.1M: Dissolve 1 g of $FeCl_3 \cdot 6\ H_2O$ in 20 ml of distilled water. Add enough distilled water to make 40 ml of solution. Put the solution in dropping bottles.

Activity 15

Pyrolysis test tubes: Use heat-resistant 25 mm X 200 mm test tubes for this activity. Since they will be difficult to clean, limit supply to one or two designated for this activity only.

Stopper assembly: Prepare a one-hole stopper to fit the test tube. Use 40 cm of glass tubing. Let the tubing protrude about 1 cm on the bottom end of the stopper. Draw out the other end into a nozzle, as described for Activity 9 (page ATE 5). Fire-polish the ends.

Organic waste mixture: Make a mixture of pieces of wood splint, paper, dried citrus-fruit peel, and polyethylene. Store in a labeled container. (Note: Fresh fruit peel produces water vapor, which may keep the gas from burning. Plastics other than polyethylene may produce poisonous gases.)

Alcohol: Students are instructed to rinse out their pyrolysis test tubes with alcohol. Any alcohol will do. Then soak the tubes overnight in kerosine, toluene, or a similar solvent.

Alternate procedure to gas burn-off: Collect the gas from the pyrolysis in test tubes by means of water displacement. Discard the first several tubes of gas, then try igniting several with a wood splint.

Activity 16

Cloth squares: Cut up cotton cloth into pieces 10 cm^2.

Wood strip: Use a strip about 2 cm X 15 cm and cut to be slightly wider than the aluminum pan you will use. Mark the strip *Activity 16.* (You could cut down an old wooden ruler or metre stick.)

Waste container: Have a labeled *Waste Oil and Water* container available; students should not dump the oil down the drain. Later, decant the waste oil for reuse or dispose of it in your trash.

Oil: Furnish the fresh oil in a suitable, labeled container. You might want to provide a funnel for easy transfer to the graduated cylinder.

Activity 17

Paper strips: Cut strips 3 cm X 5 cm.

Stopper assembly: Prepare a one-hole stopper to fit the test tube. Use 40 cm of glass tubing. Let the tubing protrude about

1 cm on the bottom end of the stopper. Draw the other end to a nozzle as described for Activity 9 (page ATE 5). Fire-polish the ends.

Samples of oil shale may be obtained from Earth Science Materials, Inc., 1900 E. Lincoln, Box 2121, Fort Collins, CO 80522.

To clean the mess, soak the tubes overnight in kerosine, toluene, or a similar solvent. You may want to mark several heat-resistant tubes just for this activity.

BACKGROUND INFORMATION

Energy Supplies

It is estimated that the world's oil and natural gas will be used up between 2015 and 2035. Coal supplies should last several centuries. The first to show concern about this were oil companies. Each year, oil industry associations have pooled information on their proven underground reserves of oil and natural gas and their annual rates of production, use, demand, stockpiling, export, and import.

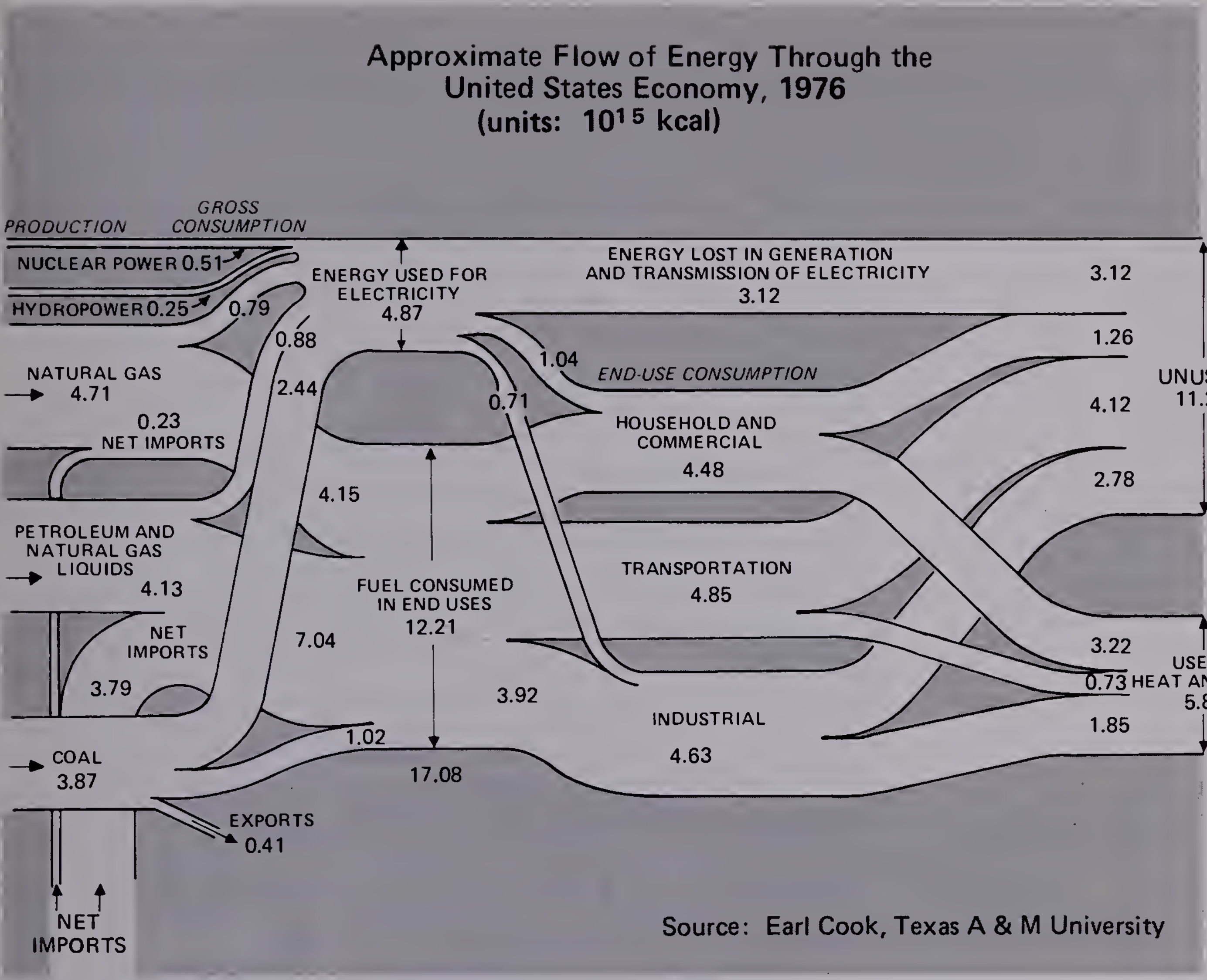
Dividing annual production into proved reserves gives the *number of years* the reserves will last at that rate of production. Each year, production increases. And each year new reserves are proved. But the number of years of reserves has started to decline. When zero is reached, the oil (or gas) will be gone. Extrapolating from the number of reserve years in past years to the number of reserve years in future years has in the past been consistent for short-term extrapolation (1 to 5 years) but not for longer periods.

For short periods, there are frequent discoveries of small new oil (or gas) fields. But discoveries of very large oil fields are increasingly rare.

The data used in Activity 7 do not attempt to predict depletion or shortage of oil or gas. They merely sum up for students, in terms of the best and latest data, trends that the students will be reading about for years to come. These trends have already profoundly affected world policies, national economics, and the way cars and other energy-consuming facilities and equipment will be built and used from now on.

Energy Use

The diagram on page ATE 9, which is drawn to scale vertically, shows the relative inputs and outputs in the U.S. energy system. The diagram fairly well approximates today's energy flow. You might want to display it for advanced students.



Approximate Flow of Energy Through the United States Economy, 1976 (units: 10^{15} kcal)

Source: Earl Cook, Texas A & M University

An important point is that energy isn't *consumed* — a term often seen in the media. Rather, energy is *degraded*. Its forms keep changing until it can no longer perform useful work. Students might also be interested in the fixed exchanged rates between mechanical energy and heat energy and between electrical energy and heat energy. Heat energy is unique in that an amount of mechanical or electrical energy can be entirely converted to heat energy, but not vice versa. (Because of this, not all the chemical energy of a fossil fuel can be converted into electrical energy in a turbogenerator.)

In a given system (say a turbogenerator), it is thermodynamically possible to convert heat entirely into work — once. Then you're stuck. To do it again, you must return the system to its original state, and that takes heat energy, some of which cannot be converted to work. This additional heat must be dissipated in order to restart the system.

Gasoline Production

The discussion of gasoline in the core of the minicourse focused on fractional distillation and catalytic cracking as the two major processes in the production of gasoline from crude oil. Manufacturers also use other refining methods to increase yields of gasoline-type hydrocarbons from crude oil. Isomerization and catalytic re-forming are used to rearrange hydrocarbon molecules to form high-octane products. Alkylation and polymerization combine gases that are too light for gasoline to form high-octane liquids for use in gasoline blending.

Octane Numbers

Octane number indicates the tendency of a gasoline to burn properly in an engine without knocking. The higher the number, the less the tendency to knock. Laboratory tests to determine the octane number are made in a specially designed one-cylinder engine by comparing marketable gasoline blends to reference fuels of known octane numbers — to isooctane with an octane number of 100 and to normal heptane with an octane number of 0. Thus, if a mixture of ninety percent isooctane and ten percent heptane is required in the engine to duplicate the knocking of the test gasoline, the latter is rated Research Octane Number (RON) 90. A different value — the Motor Octane Number (MON) — is obtained by comparing the test gasoline to reference fuels under a different and more rigorous set of engine conditions. For any gasoline, MON will be lower than RON.

In the past, the existence of two octane rating systems has caused some confusion. Automobile owner's manuals often used MON requirements, whereas gasoline manufacturers used RONs. To eliminate this problem, the U.S. Cost of Living Council in 1973 required that gasoline pumps display a number that is the average of the RON and MON of the gasoline. Owner's manuals also conform to this standard, which is a good indication of the octane requirements of recent model cars. The octane numbers used in the core of this minicourse are those values and are averages of data obtained from several major oil companies.

You might want to point out to your students that all gasoline, regardless of octane number, has about the same energy content — about 7250 kilocalories per litre — when burned completely. Energy losses are caused by incomplete burning and by the mechanical effects of knocking. Using a gasoline of octane number higher than that needed to prevent knocking will increase cost but not performance.

Gasoline Composition and Knocking

There are two basic procedures used for reducing the knocking problem in gasoline. One is to use only hydrocarbons that burn satisfactorily in a high-compression engine — like branched-chain and aromatic hydrocarbons. They are less prone to knock, but are usually more expensive than isomeric straight-chain (normal) hydrocarbons. The second procedure is to add antiknock agents, the best known of which is tetraethyllead, $(C_2H_5)_4Pb$, a very toxic substance.

Additives, in general, control knocking by slowing down free radical reactions in the combustion chamber. With tetraethyllead, other halogen compounds like 1, 2-dibromoethane must also be added to help remove the lead from the engine. These compounds combine to form lead bromide or lead chloride when the gasoline is burned. They are then released as condensable vapors through the exhaust into the atmosphere. Most gasolines contain only a few tenths of a percent of these additives — a half to one gram of lead per litre. But worldwide total emissions amount to millions of kilograms of lead each year.

Other chemicals are also added to gasoline. Phosphorus and boron compounds help prevent the undesired ignition of new fuel from glowing particles remaining in the combustion chamber after the previous ignition. Phosphorus compounds also help prevent spark-plug deposits from becoming electrically conductive enough to allow the charge to leak away. Boron compounds prevent sulfur compounds in gasoline from rendering tetraethyllead ineffective.

Phenylenediamine, aminophenols, dibutyl-p-cresol, and orthoalkylated phenols are added as antioxidants. They prevent the formation of peroxides that can lead to gum formation and knock. Antirust agents (such as calcium and sodium sulfonates), antiicing agents, detergents, upper cylinder lubricants, and dyes are also added in varying amounts at certain times of the year. It is this variety of hydrocarbons and additives that make one manufacturer's gasoline different from another's.

Measures

In the student's materials, *teaspoon* and *tablespoon* are used, when appropriate, for the volume of solids to be obtained. Such measures are used instead of asking students to weigh out solids because they are simpler and because similar size metric spoons for dispensing small amounts are not yet readily available.

Eye Safety

ISIS recommends that students wear safety goggles whenever they are working in a laboratory situation. Although a particular student may not be working with hazardous materials, other students nearby may be.

Working with Chemicals

Before students begin working with chemicals, spend some time instructing them about general laboratory safety and about appropriate precautions for working safely with chemicals. There are several safety suggestions in *Managing ISIS*.

Disposal and Conservation of Materials

You will have to direct students about methods of safely conserving and disposing of various liquids and solids. Refer to *Managing ISIS* for suggestions.

EVALUATION SUGGESTIONS

In addition to the *Minicourse Test*, answers to which are provided with the test, you may want to use the following essay questions.

Essay Questions

Two essay questions are included here with model answers for your convenience. Both suggestions relate to core activities.

1. Using an example, explain what is meant by the statement, "Energy is never lost but is simply changed from one form to another."

Answer: In an automobile engine, the chemical energy of burning fuels is released as heat. Some of the heat goes directly to the atmosphere. The rest is changed into the energy of motion in the moving pistons. The energy of the moving pistons is then changed into the energy of moving tires. The energy of the moving tires is then changed into the energy of the moving car, which eventually is changed back into heat through friction (use of the brakes and other unavoidable frictional conversion to heat in the various stages). The heat is then released into the atmosphere.

2. What would you say to a person who says that people do not have to be concerned about using up the supply of fossil fuels, since these fuels are constantly being produced by natural processes underground?

Answer: For all practical purposes, once people use up the fossil fuels that are in the ground now, that's it. It took millions of years for those fuels to form. People are using them up at such a rapid rate that new supplies cannot possibly be formed fast enough to fill the needs of people in the foreseeable future.

REFERENCES

Basic Petroleum Data Book — Petroleum Industry Statistics. Washington, D.C.: American Petroleum Institute, 1975.
This loose-leaf compendium of basic data on petroleum and natural gas is updated periodically.

Bent, Henry A. "Entropy and the Energy Crisis." *The Science Teacher*, Vol, 44, No. 5 (May, 1977). pp. 25-31.
The thermodynamics of energy conservation are treated in a way suitable for teachers.

"Be Sure You Understand Octane Numbers." *Chemistry* 47 (January, 1974).
The short discussions of octane numbers and of the history of antiknock additives are appropriate for high school students.

Flower, A.R. "World Oil Production." *Scientific American*, 303 (March, 1978), pp. 42-49.
Using tables and graphs, the author describes how to forecast the world's oil supply and presents projections to the year 2000. This article is suitable for advanced students and as a reference for teachers.

Fowler, John W. *Energy-Environment Source Book*. Washington, D.C.: National Science Teachers Association, 1975.
This large paperback is a source for background facts and figures.

Johnston, D.O.; Netterville, J.T.; Wood, J.L.; and Jones, M.M. *Chemistry and the Environment*. Philadelphia: W.S. Saunders Company, 1973.
Useful teacher background information on air pollution and automotive chemistry is presented in Chapters 19 and 21.

Mills, G. Alex. "Ubiquitous Hydrocarbons." *Chemistry*, Reprint no. 98 (February and March, 1971).

Hydrocarbon structure and reactions are treated. The article is suitable for advanced students.

Science. 184 (April 19, 1974).

Entirely devoted to problems of energy use, this issue is a clear, sophisticated, and objective presentation.

Science. 199 (February 10, 1978).

Nine articles on energy use in today's society are included in this technical presentation suitable for teacher reference.

Science Digest. Vol. 82, no. 4 (October, 1977).

The issue is entirely devoted to articles on energy and how people may live in 1985. Energy alternatives are summarized.

Scientific American. 225 (September, 1971).

Entirely devoted to "energy and power," this issue is exceptionally heavily illustrated and clear, although less detailed than the treatment of the same topics in *Science* 184.

Wilson, Mitchell, and the Editors of Time-Life Books. *Energy*. New York: Time, Inc., 1967.

This easily readable work describes the sources and uses of the common forms of energy.

The following agencies are excellent sources for obtaining pamphlets, posters, booklets, and brochures on various fossil fuels. Samples of petroleum and coal may also be available.

American Gas Association, Inc.
Education Services
1515 Wilson Boulevard
Arlington, VA 22209

American Petroleum Institute
Educational Services
1801 K Street, N.W.
Washington, DC 20006

National Coal Association
Educational Services
1130 Seventeenth Street, N.W.
Washington, DC 20036

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Special Consultants: Ronald J. Clark, Professor of Chemistry, Florida State University, Tallahassee, Florida; Dr. David F. MacInnes, Chairman, Chemistry Department, Guilford College, Greensboro, North Carolina

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FOREWORD

Evidence has been mounting that something is missing from secondary science teaching. More and more, students are rejecting science courses and turning to subjects that they consider to be more practical or significant. Numerous high school science teachers have concluded that what they are now teaching is appropriate for only a limited number of their students.

As their concern has mounted, many science teachers have tried to find instructional materials that encompass more appropriate content and that allow them to work individually with students who have different needs and talents. For the most part, this search has been frustrating because presently such materials are difficult, if not impossible, to find.

The Individualized Science Instructional System (ISIS) project was organized to produce an alternative for those teachers who are dissatisfied with current secondary science textbooks. Consequently, the content of the ISIS materials is unconventional as is the individualized teaching method that is built into them. In contrast with many current science texts which aim to "cover science," ISIS has tried to be selective and to limit our coverage to the topics that we judge will be most useful to today's students.

Obviously the needs and problems of individual schools and students vary widely. To accommodate the differences, ISIS decided against producing tightly structured, pre-sequenced textbooks. Instead, we are generating short, self-contained modules that cover a wide range of topics. The modules can be clustered into many types of courses, and we hope that teachers and administrators will utilize this flexibility to tailor-make curricula that are responsive to local needs and conditions.

ISIS is a cooperative effort involving many individuals and agencies. More than 75 scientists and educators have helped to generate the materials, and hundreds of teachers and thousands of students have been involved in the project's nationwide testing program. All of the ISIS endeavors have been supported by generous grants from the National Science Foundation. We hope that ISIS users will conclude that these large investments of time, money, and effort have been worthwhile.

Ernest Burkman
ISIS Project
Tallahassee, Florida

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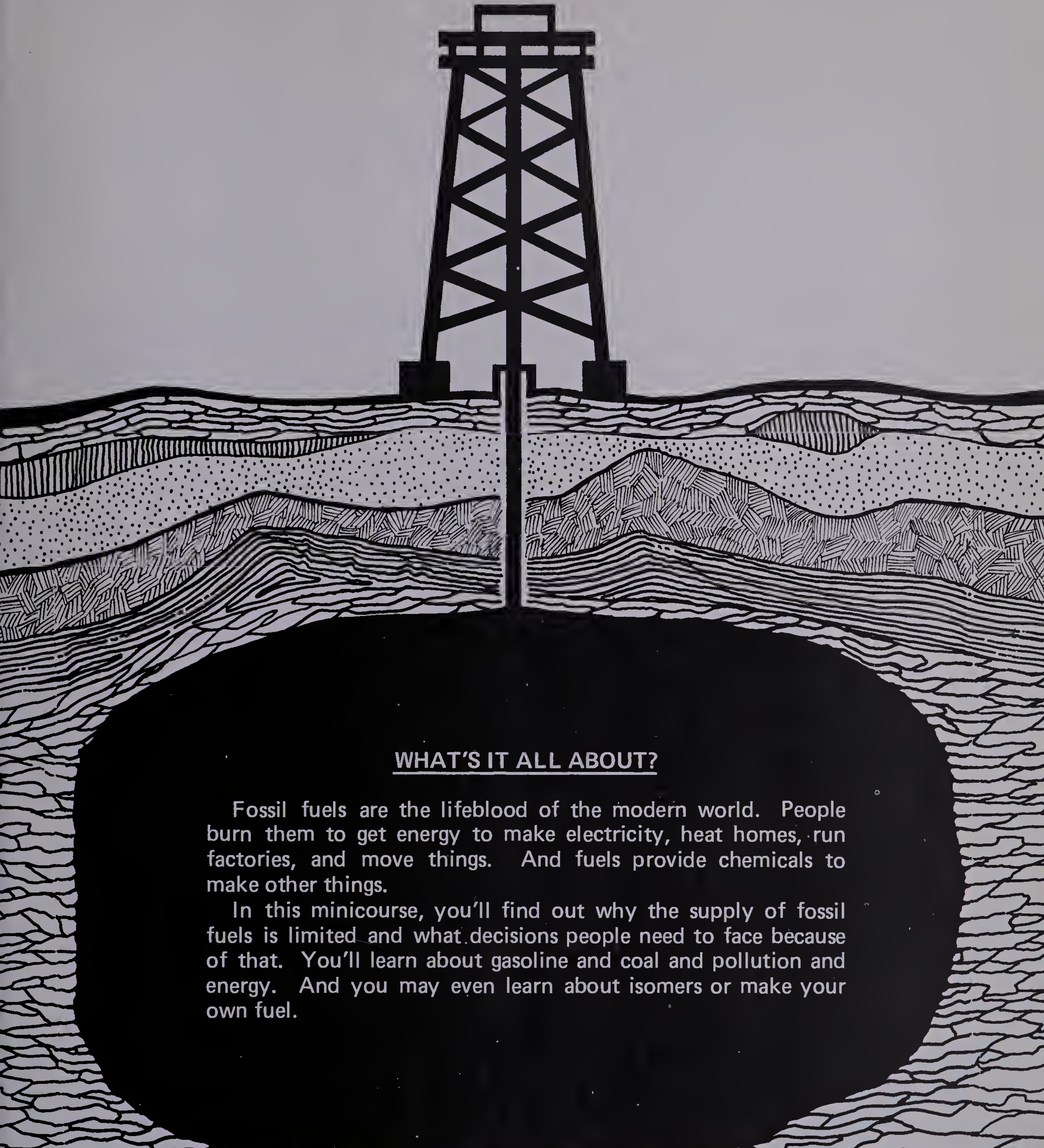
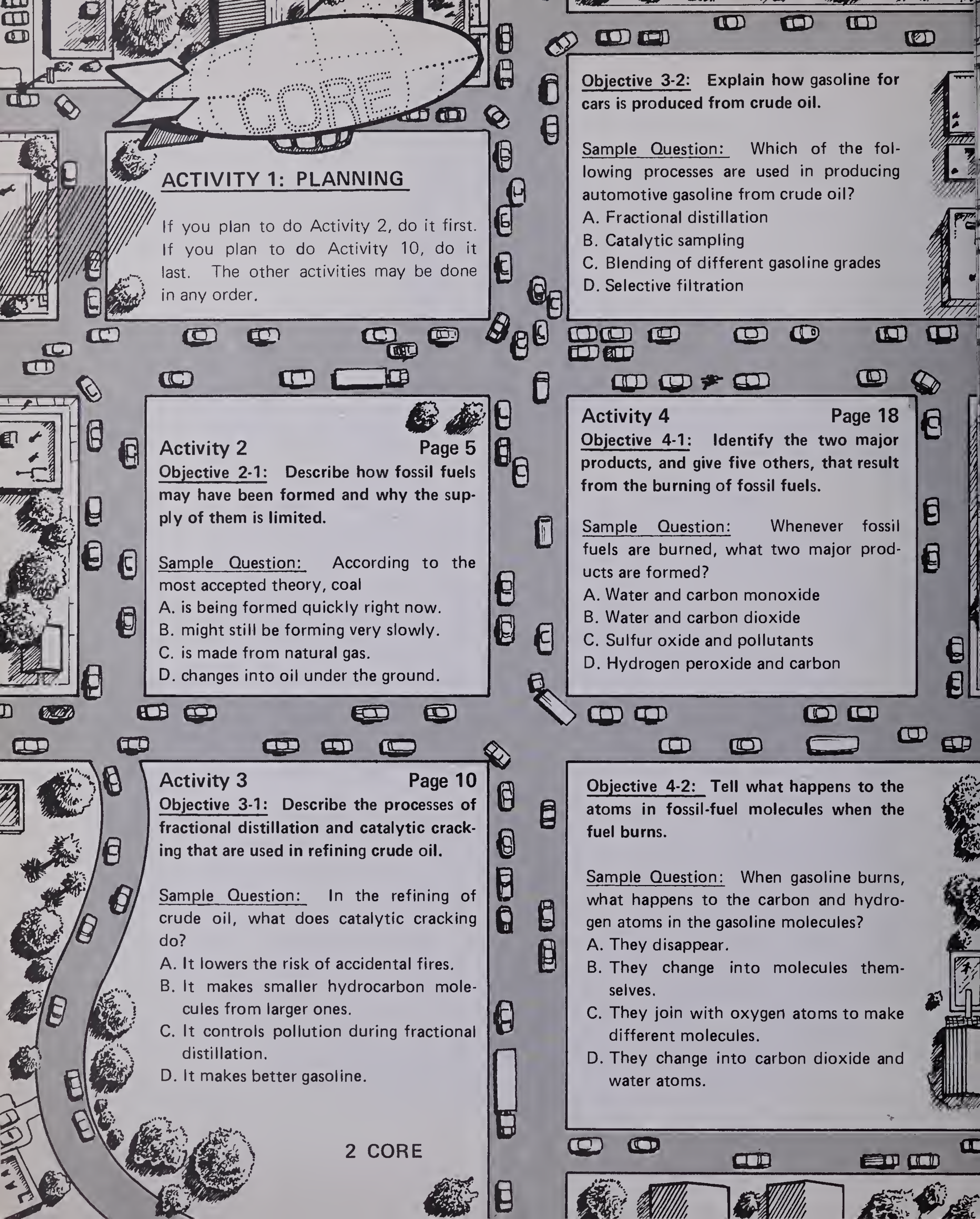


WHAT'S IT ALL ABOUT?

Fossil fuels are the lifeblood of the modern world. People burn them to get energy to make electricity, heat homes, run factories, and move things. And fuels provide chemicals to make other things.

In this minicourse, you'll find out why the supply of fossil fuels is limited and what decisions people need to face because of that. You'll learn about gasoline and coal and pollution and energy. And you may even learn about isomers or make your own fuel.



ACTIVITY 1: PLANNING

If you plan to do Activity 2, do it first. If you plan to do Activity 10, do it last. The other activities may be done in any order.

Activity 2 Page 5

Objective 2-1: Describe how fossil fuels may have been formed and why the supply of them is limited.

Sample Question: According to the most accepted theory, coal
A. is being formed quickly right now.
B. might still be forming very slowly.
C. is made from natural gas.
D. changes into oil under the ground.

Activity 3 Page 10

Objective 3-1: Describe the processes of fractional distillation and catalytic cracking that are used in refining crude oil.

Sample Question: In the refining of crude oil, what does catalytic cracking do?
A. It lowers the risk of accidental fires.
B. It makes smaller hydrocarbon molecules from larger ones.
C. It controls pollution during fractional distillation.
D. It makes better gasoline.

Objective 3-2: Explain how gasoline for cars is produced from crude oil.

Sample Question: Which of the following processes are used in producing automotive gasoline from crude oil?
A. Fractional distillation
B. Catalytic sampling
C. Blending of different gasoline grades
D. Selective filtration

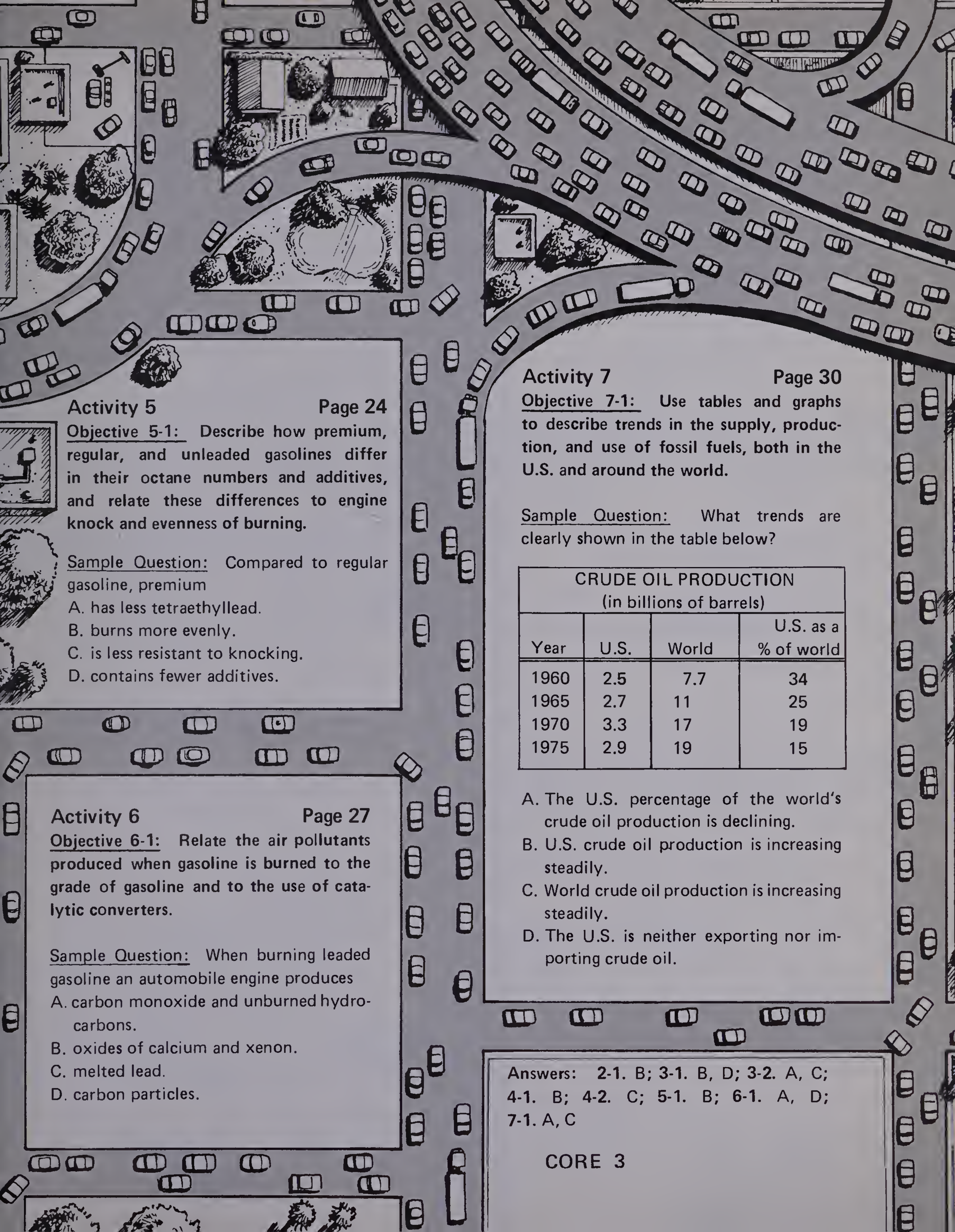
Activity 4 Page 18

Objective 4-1: Identify the two major products, and give five others, that result from the burning of fossil fuels.

Sample Question: Whenever fossil fuels are burned, what two major products are formed?
A. Water and carbon monoxide
B. Water and carbon dioxide
C. Sulfur oxide and pollutants
D. Hydrogen peroxide and carbon

Objective 4-2: Tell what happens to the atoms in fossil-fuel molecules when the fuel burns.

Sample Question: When gasoline burns, what happens to the carbon and hydrogen atoms in the gasoline molecules?
A. They disappear.
B. They change into molecules themselves.
C. They join with oxygen atoms to make different molecules.
D. They change into carbon dioxide and water atoms.



Activity 5

Page 24

Objective 5-1: Describe how premium, regular, and unleaded gasolines differ in their octane numbers and additives, and relate these differences to engine knock and evenness of burning.

Sample Question: Compared to regular gasoline, premium

A. has less tetraethyllead.
B. burns more evenly.
C. is less resistant to knocking.
D. contains fewer additives.

Activity 6

Page 27

Objective 6-1: Relate the air pollutants produced when gasoline is burned to the grade of gasoline and to the use of catalytic converters.

Sample Question: When burning leaded gasoline an automobile engine produces

A. carbon monoxide and unburned hydrocarbons.
B. oxides of calcium and xenon.
C. melted lead.
D. carbon particles.

Activity 7

Page 30

Objective 7-1: Use tables and graphs to describe trends in the supply, production, and use of fossil fuels, both in the U.S. and around the world.

Sample Question: What trends are clearly shown in the table below?

CRUDE OIL PRODUCTION (in billions of barrels)			
Year	U.S.	World	U.S. as a % of world
1960	2.5	7.7	34
1965	2.7	11	25
1970	3.3	17	19
1975	2.9	19	15

A. The U.S. percentage of the world's crude oil production is declining.
B. U.S. crude oil production is increasing steadily.
C. World crude oil production is increasing steadily.
D. The U.S. is neither exporting nor importing crude oil.

Answers: **2-1.** B; **3-1.** B, D; **3-2.** A, C; **4-1.** B; **4-2.** C; **5-1.** B; **6-1.** A, D; **7-1.** A, C

CORE 3

Objective 7-2: **Identify the fossil fuels that are most abundant and least abundant in the U.S., and tell why the U.S. must import crude oil.**

Sample Question: The U.S. must import crude oil because

A. importing helps the nation's crude oil supplies last longer.
B. domestic production falls short of demand.
C. production greatly exceeds supply.
D. domestic oil is of low quality.

Activity 8 Page 36

Objective 8-1: **Describe how the mining of coal may affect the environment.**

Sample Question: One big problem in the surface mining of coal is

A. air pollution.
B. underground explosions.
C. cave-ins.
D. scarring and eroding of the land.

Objective 8-2: **Describe the environmental problems in extracting and transporting crude oil and with producing oil from oil shale.**

Sample Question: If an oil leak occurs on an offshore oil rig, which of the following may occur?

A. Damage to beaches
B. Cave-ins
C. Introduction of dangerous substances into the water
D. Tidal disturbances

Activity 9 Page 42

Objective 9-1: **Describe how energy is conserved when fossil fuels are burned to generate electricity.**

Sample Question: When electricity is made by burning fossil fuels,

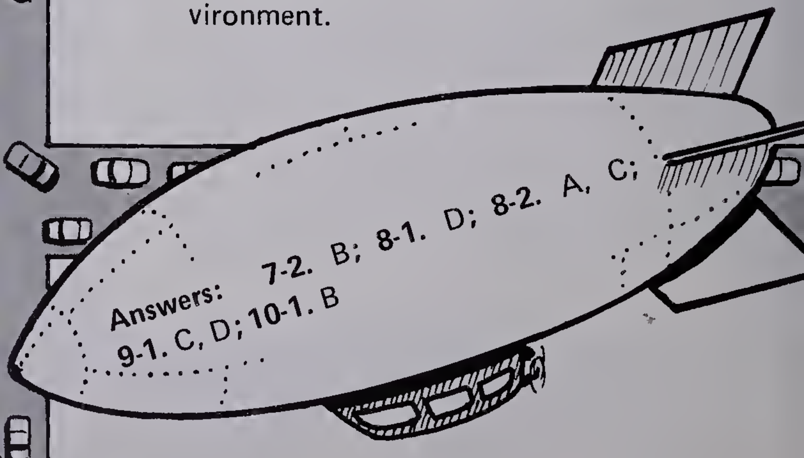
A. all of the chemical energy stored in the fuel is converted to electrical energy.
B. some of the chemical energy stored in the fuel is destroyed.
C. more than half of the chemical energy stored in the fuel is given up to the surroundings as heat energy.
D. the total energy before the change equals the total energy after the change.

Activity 10 Page 47

Objective 10-1: **Describe the pros and cons of using coal instead of oil or natural gas to generate electricity, considering each fuel's availability, cost, efficiency, and environmental side effects.**

Sample Question: Compared to oil or natural gas as an electrical energy source, coal is

A. less polluting.
B. more readily available.
C. more efficient.
D. obtained with less damage to the environment.



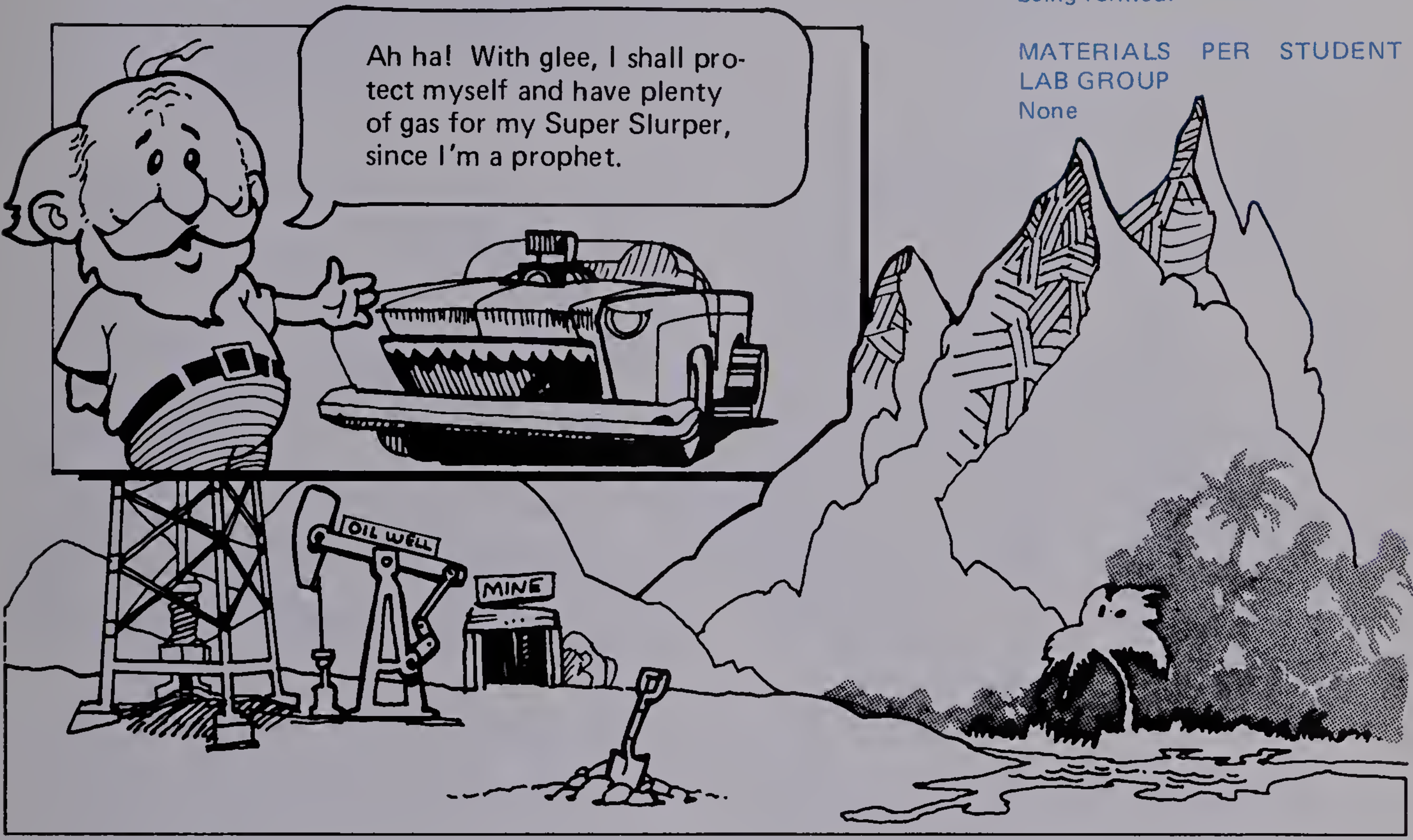
Answers: 7-2. B; 8-1. D; 8-2. A, C;
9-1. C, D; 10-1. B

ACTIVITY 2: HERE TODAY, BUT GONE TOMORROW

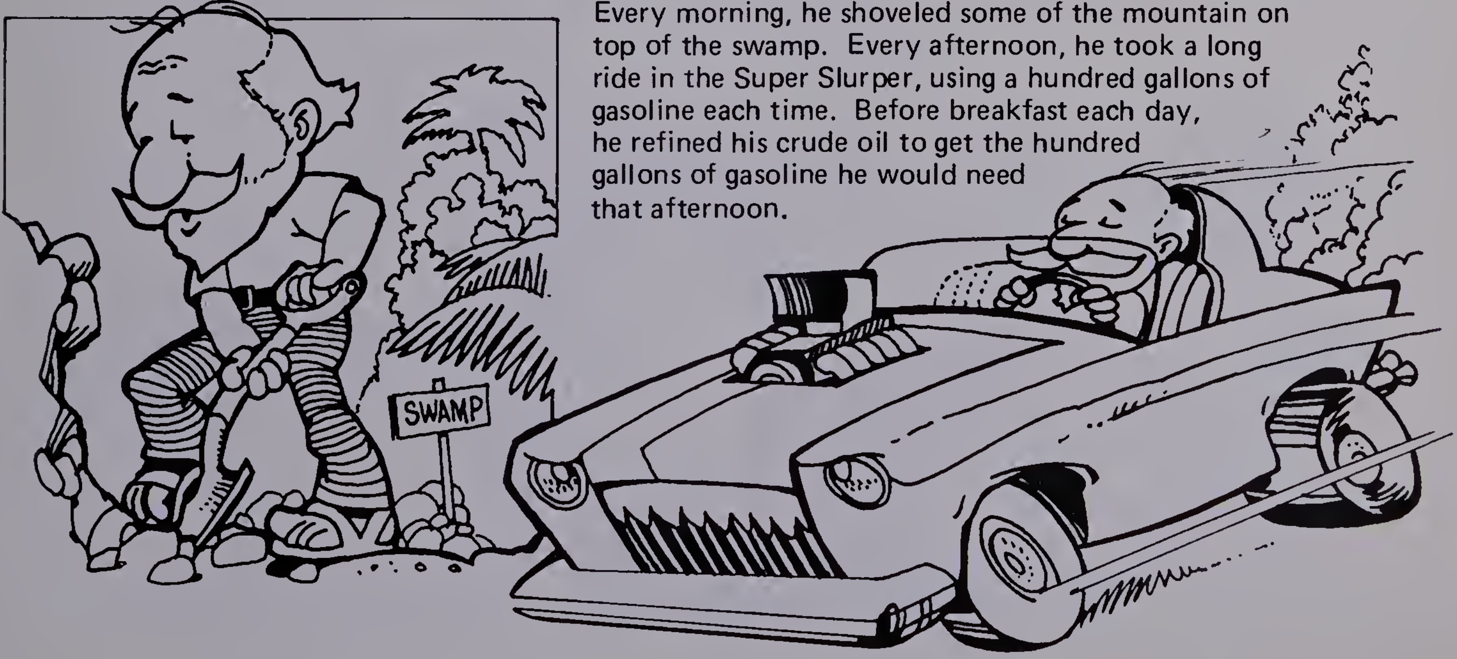
ACTIVITY EMPHASIS: Fossil fuels were and probably are still being made from remains of plants and animals put under tremendous pressure and high temperature. Their supply is limited because people are using them much faster than they are being formed.

MATERIALS PER STUDENT LAB GROUP
None

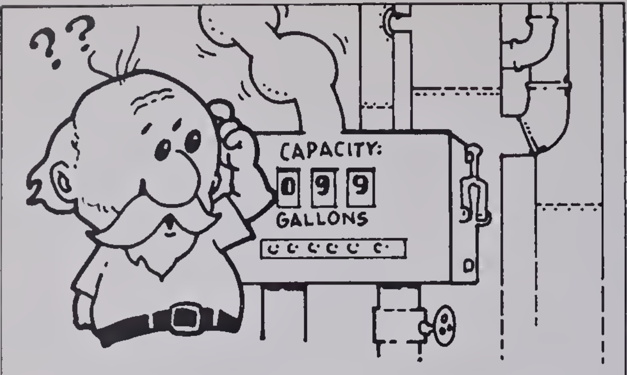
Once upon a time, not so long ago,
there lived a prophet who
foresaw an energy crisis.


Ah ha! With glee, I shall protect myself and have plenty of gas for my Super Slurper, since I'm a prophet.
OIL WELL
MINE

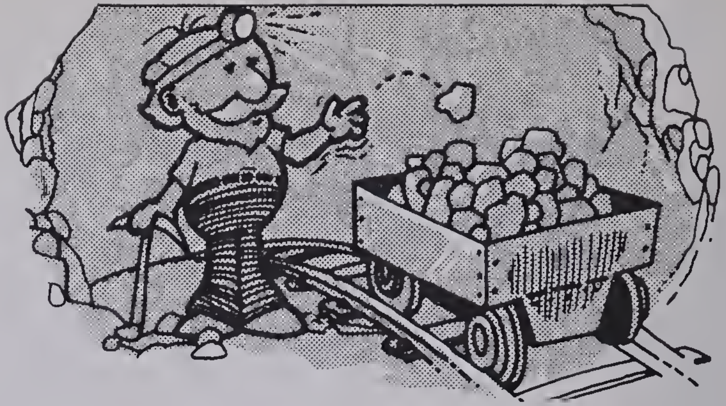
He had heard about how gasoline was made, so he bought an oil well, a coal mine, and a swamp with lush plants growing and lots of little animals living there. He also bought a large mountain and a shovel.



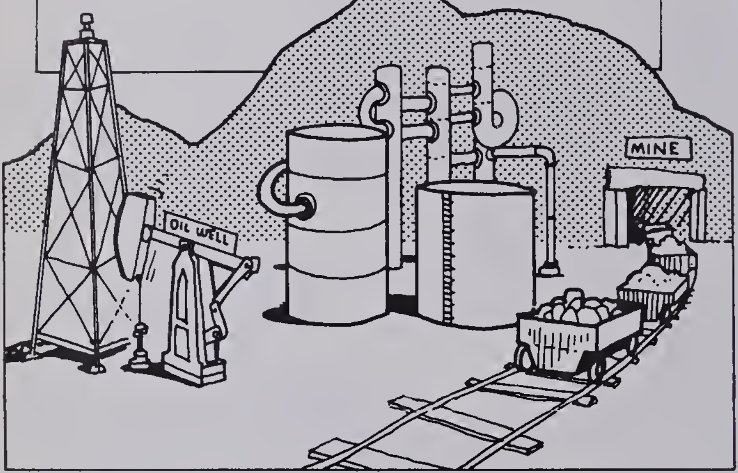
Every morning, he shoveled some of the mountain on top of the swamp. Every afternoon, he took a long ride in the Super Slurper, using a hundred gallons of gasoline each time. Before breakfast each day, he refined his crude oil to get the hundred gallons of gasoline he would need that afternoon.



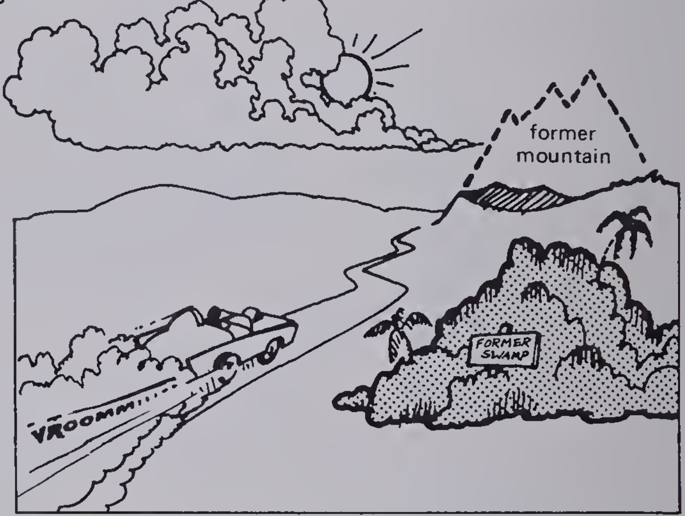
Things went well for a while. But then came a day when he was able to get only ninety-nine gallons of gasoline before breakfast. That afternoon, he shortened his ride a little bit.



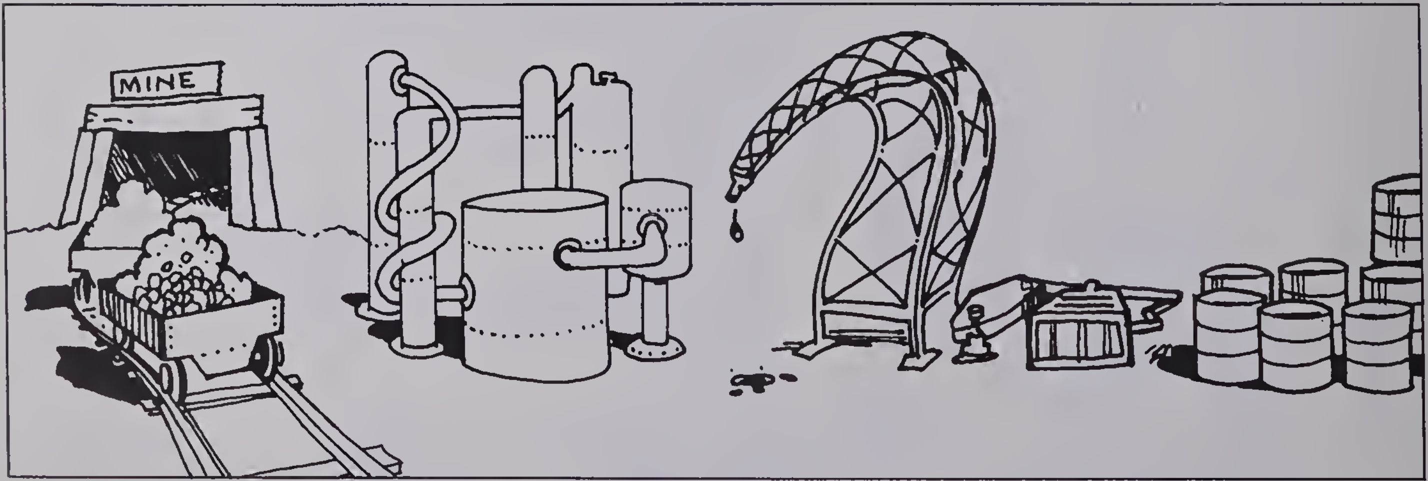
The next day, he started to mine a little coal from his mine so that he could convert the coal into gasoline.



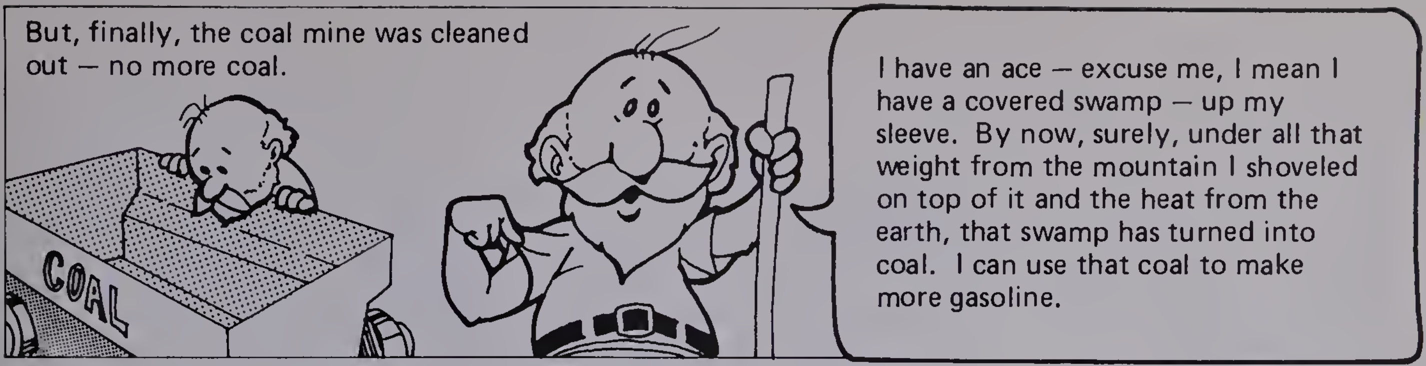
Pretty soon, he was getting less and less gasoline from the oil well and more and more from the coal. For a while, he was able to get a little bit ahead and make about a hundred twenty-five gallons each day.



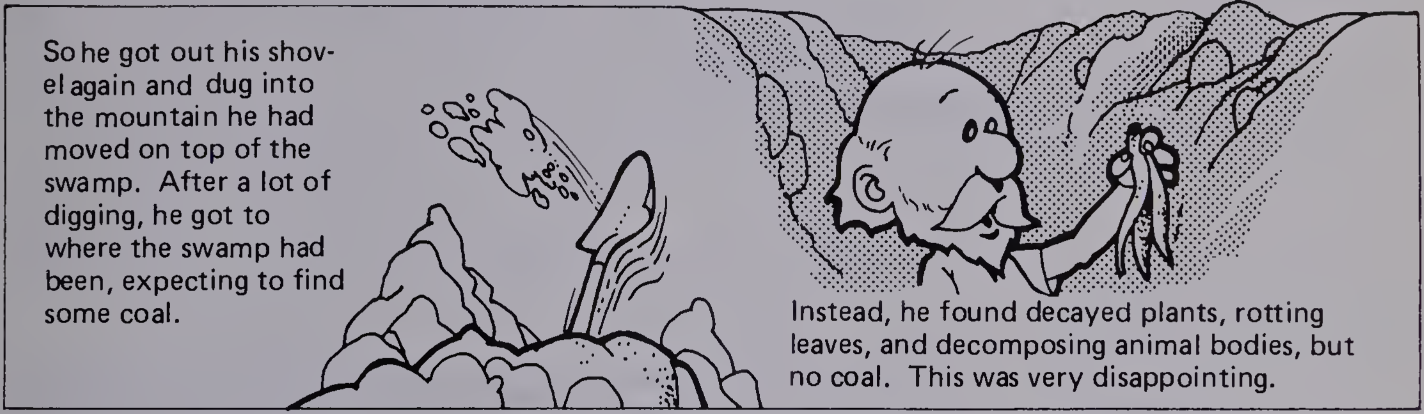
Some of this extra he used by taking longer rides, especially in the evenings. And some of the extra he stored because by now he was getting worried about how things would turn out. Of course, he still had that swamp — all covered with the mountain by this time.



Sure enough, the oil well finally gave out — no more crude oil to make gasoline from. And the coal mine was close to being exhausted. But he went on in the same way, making gasoline from the coal as best he could and using some of the gasoline he had stored away.

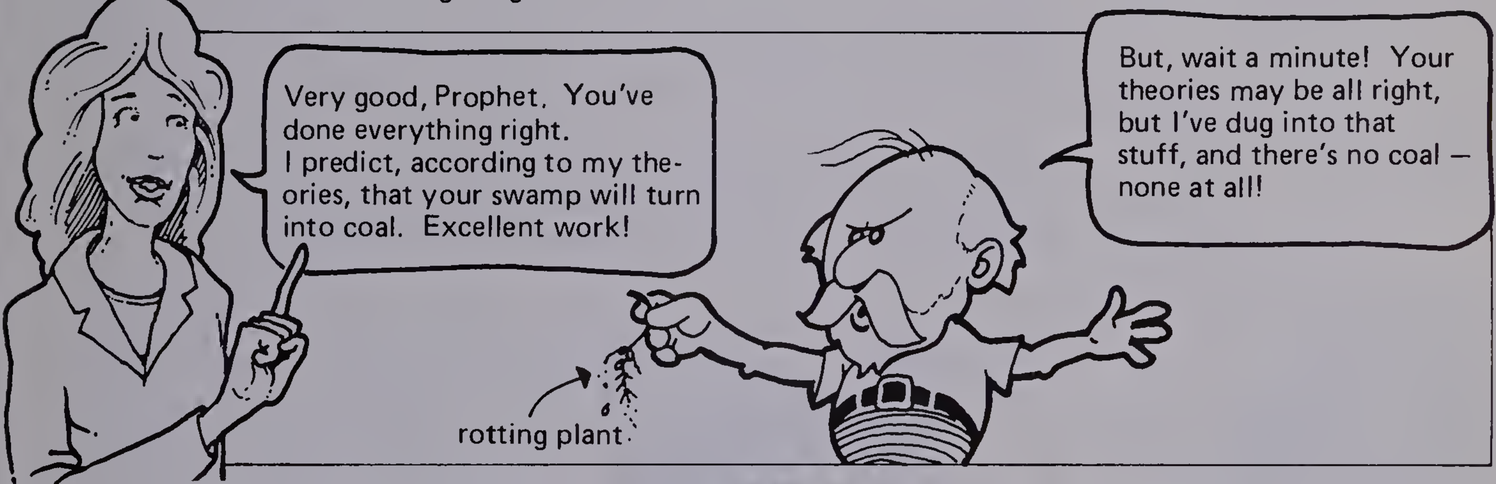

But, finally, the coal mine was cleaned out — no more coal.

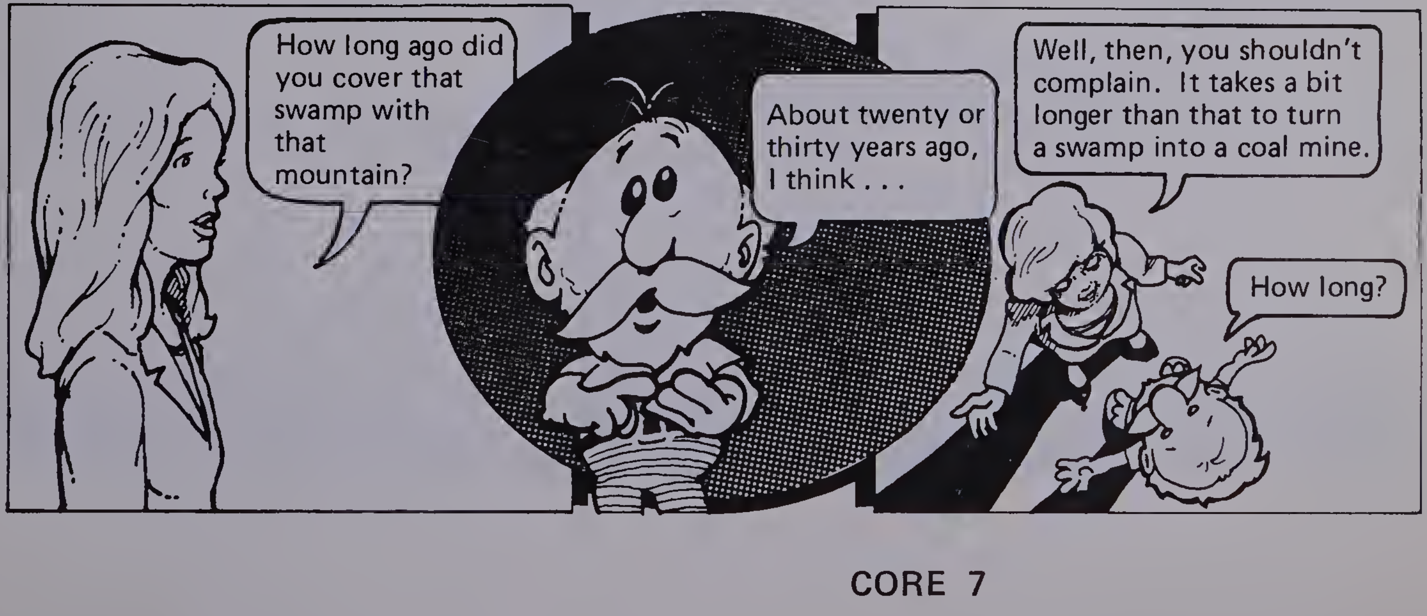
COAL
I have an ace — excuse me, I mean I have a covered swamp — up my sleeve. By now, surely, under all that weight from the mountain I shoveled on top of it and the heat from the earth, that swamp has turned into coal. I can use that coal to make more gasoline.


So he got out his shovel again and dug into the mountain he had moved on top of the swamp. After a lot of digging, he got to where the swamp had been, expecting to find some coal.

Instead, he found decayed plants, rotting leaves, and decomposing animal bodies, but no coal. This was very disappointing.

He called a geologist friend to look at the situation and tell him what to do.


Very good, Prophet. You've done everything right.
I predict, according to my theories, that your swamp will turn into coal. Excellent work!
But, wait a minute! Your theories may be all right, but I've dug into that stuff, and there's no coal — none at all!
rotting plant


How long ago did you cover that swamp with that mountain?
About twenty or thirty years ago, I think . . .
Well, then, you shouldn't complain. It takes a bit longer than that to turn a swamp into a coal mine.
How long?

Oh, usually something like fifty to one hundred million years!
!!

For the rest of his life, the prophet walked in the afternoon and rode his bicycle now and then in the evenings.

2-1. [Answers will vary and should be quite interesting. The point of the story is that people are using up fossil fuels faster than the fuels can be formed. Thus, one moral might be that if people don't decrease their usage, they'll be walking or riding bicycles.]

2-2. A fossil fuel is a fuel formed from the remains of dead plants and animals.

- 2-1. Most "once-upon-a-time" stories have a moral. What's one moral of this story?

Crude oil, coal, and natural gas are called *fossil fuels*. Scientists believe they were gradually formed from the remains of dead plants and animals.

- 2-2. What is a fossil fuel?

As the prophet's story suggested, plant and animal remains don't change into fossil fuels very fast. The process takes millions of years. Here's what scientists think happened.

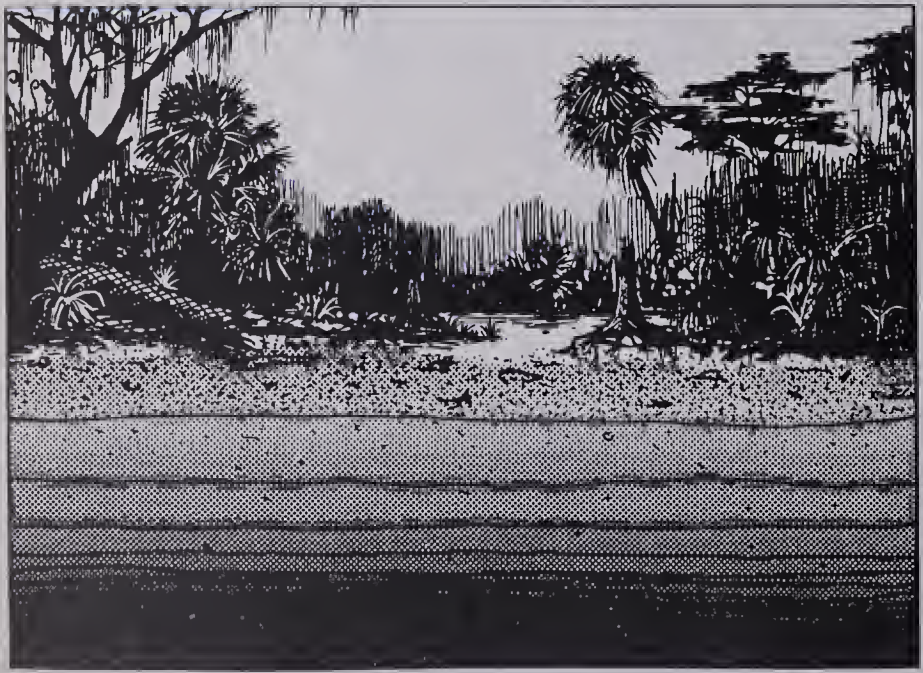


Figure 2-1

The main coal-forming age on Earth was about 300 million years ago. During that age plants and animals lived in hot swamps. As they grew old and died, the plants and animals decayed and became part of the ground. New plants and animals grew and lived on top of their remains. And when the new organisms died, they too sank into the ground, and so on.

Scientists think that over the years thick layers of these organic remains sank deeper and deeper into the soft, swampy ground (see Figure 2-1).

● 2-3. What do scientists believe happened to plant and animal remains from swamps?

2-3. The remains got buried deeper under the swampy ground.

At some later time, the swamps disappeared. The layers of remains got covered with layers of mud and sand and were pushed deeper and deeper. Far below the surface it's hotter. And there's a lot of pressure, too, from the weight of materials on top. So the layers of remains were treated to a lot of hot crowding. Naturally, some changes took place. Mud and sand turned to rock, and the layers of swamp remains turned to coal.

This was a very slow process. As the prophet's geologist friend said, it takes several million years for a layer of coal to form. It also takes a lot of organic remains — the remains of nine to twelve thousand years of swamp life turn into a layer of coal only about thirty centimetres thick.

☆ **2-4. Describe how scientists think coal was formed.**

2-4. Remains of swamp life were buried and then subjected to tremendous heat and pressure. Over millions of years, this changed the remains into coal.

Other swampy places may have been covered only a few thousand years ago or so. And right now, more coal is slowly being made in those places. It won't be much help, though. People are using coal much faster than it can be formed. So, practically speaking, coal is a nonrenewable resource. Once the coal in the ground has been used up, that's it!

Scientists are not quite as sure about how crude oil and natural gas were formed. It probably wasn't in swamps. Instead, they may have been formed a few million years ago in the floors of oceans and seas.

The Dismal Swamp in Virginia and North Carolina is thought to be a typical and contemporary coal accumulation site.

Microscopic sea life died, got covered up by mud and sand, and was then subjected to lots of pressure and heat (see Figure 2-2 below). As time went on, the high temperature and pressure changed the remains into crude oil and natural gas.

Many geologists think that formation of petroleum begins immediately upon burial.

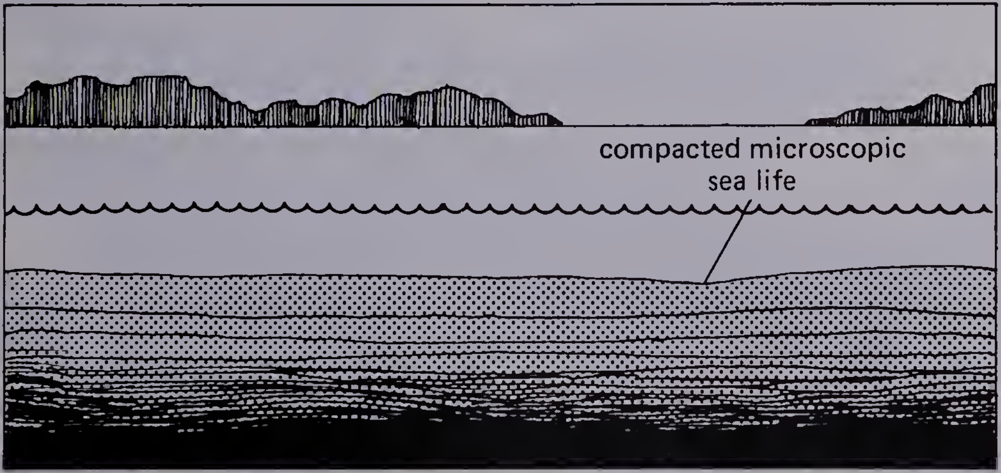


Figure 2-2

2-5. Remains of sea life were buried underwater. Then they were subjected to high temperature and pressure, changing the remains into crude oil and natural gas.

☆ **2-5. How do scientists think crude oil and natural gas were formed?**

One thing is certain – coal is different from crude oil and natural gas. Coal is composed mostly of carbon, whereas crude oil and natural gas are mostly hydrocarbon molecules. So it's reasonable to assume that they formed from different source materials.

Are new supplies of crude oil and natural gas forming now? Possibly, but the process is very slow. It will take thousands and thousands of years to make use of the results. For all practical purposes, what's already formed is all there is.

2-6. People are using them up much faster than they can be formed.

☆ **2-6. Why is the supply of fossil fuels limited?**

ACTIVITY EMPHASIS: Fractional distillation of crude oil, cracking of the large molecule fractions, and blending produce useful gasoline.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

Varying types and amounts of impurities and differing hydrocarbon molecular weights cause different colors and viscosities of crude oil.

ACTIVITY 3: HOW CRUDE!

Natural petroleum, often called *crude oil*, comes from under the ground. Scientists believe that it has been produced over millions of years by the changing of microscopic sea life buried in Earth's crust. In this activity you will look at the substances that make up this very important fossil fuel, crude oil.

Chemists have found that crude oil is a mixture of many different compounds. But most of these compounds are made from just two elements – hydrogen and carbon. So they're called *hydrocarbons*. The other compounds are "impurities" such as compounds of sulfur and oxygen, salts, and water (see Figure 3-1 below).

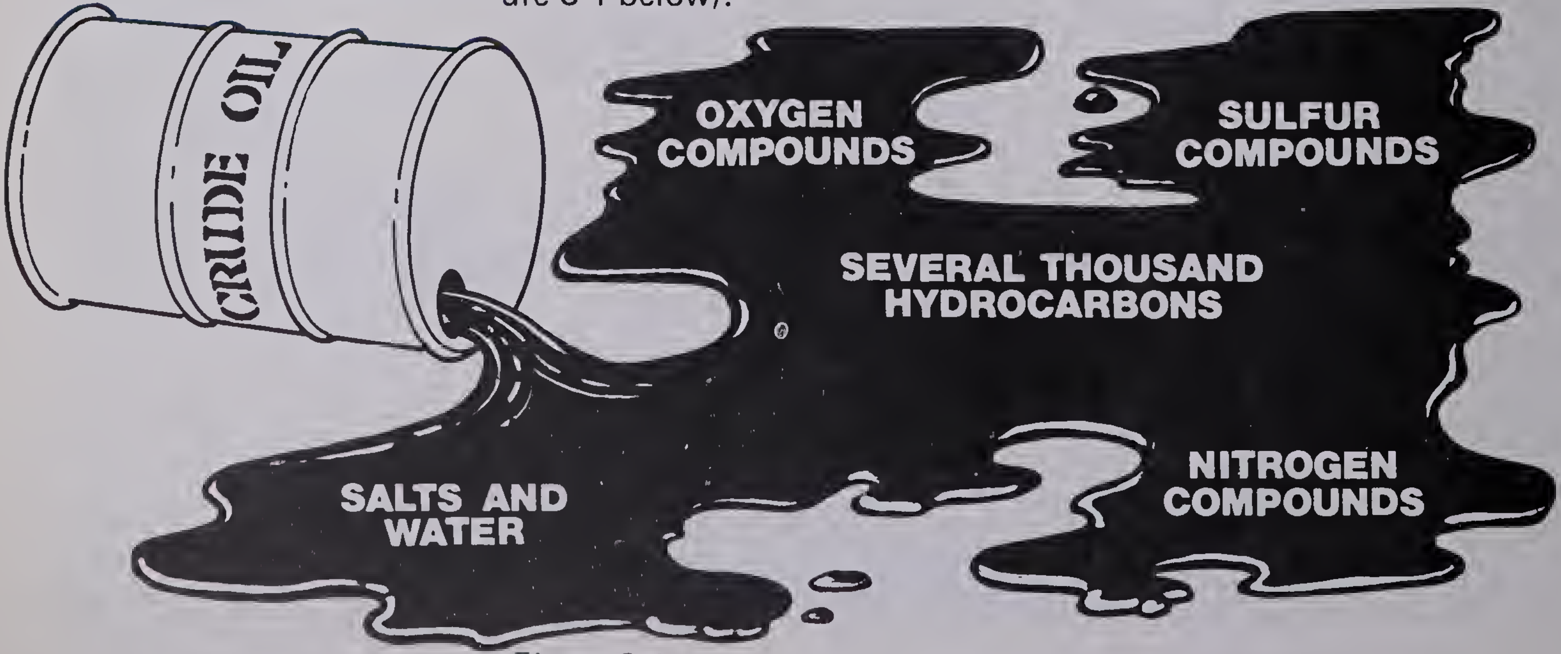


Figure 3-1

- 3-1. Not all crude oil is the same. Why do you suppose this is?

In its natural state crude oil is not too useful. But it contains many very useful hydrocarbons. Since different hydrocarbons boil/condense at different temperatures, they can be extracted from the crude oil by a process known as *fractional distillation.*

To observe this process you'll need about thirty minutes and the following equipment.

safety goggles
ring stand with utility clamp
large test tube
3 medium test tubes
test-tube rack
boiling chip
Bunsen burner or other heat source
asbestos pad
delivery assembly (two-hole stopper with short bent-glass tubing and thermometer inserted)
15 ml of isopropyl alcohol—water mixture
stirring rod
graduated cylinder
grease pencil
4 paper strips, 10 cm X 1 cm
60-cm length of rubber tubing

If you're not sure you know how to use a burner, read "Resource Unit 17: Using a Burner" now. If you don't know how to use and care for a thermometer, read "Resource Unit 14: Using a Thermometer" now. Then begin Step A (page 12).

CAUTION	Remember to wear your safety goggles.

3-1. Different crude oils have different amounts of different hydrocarbons and impurities.

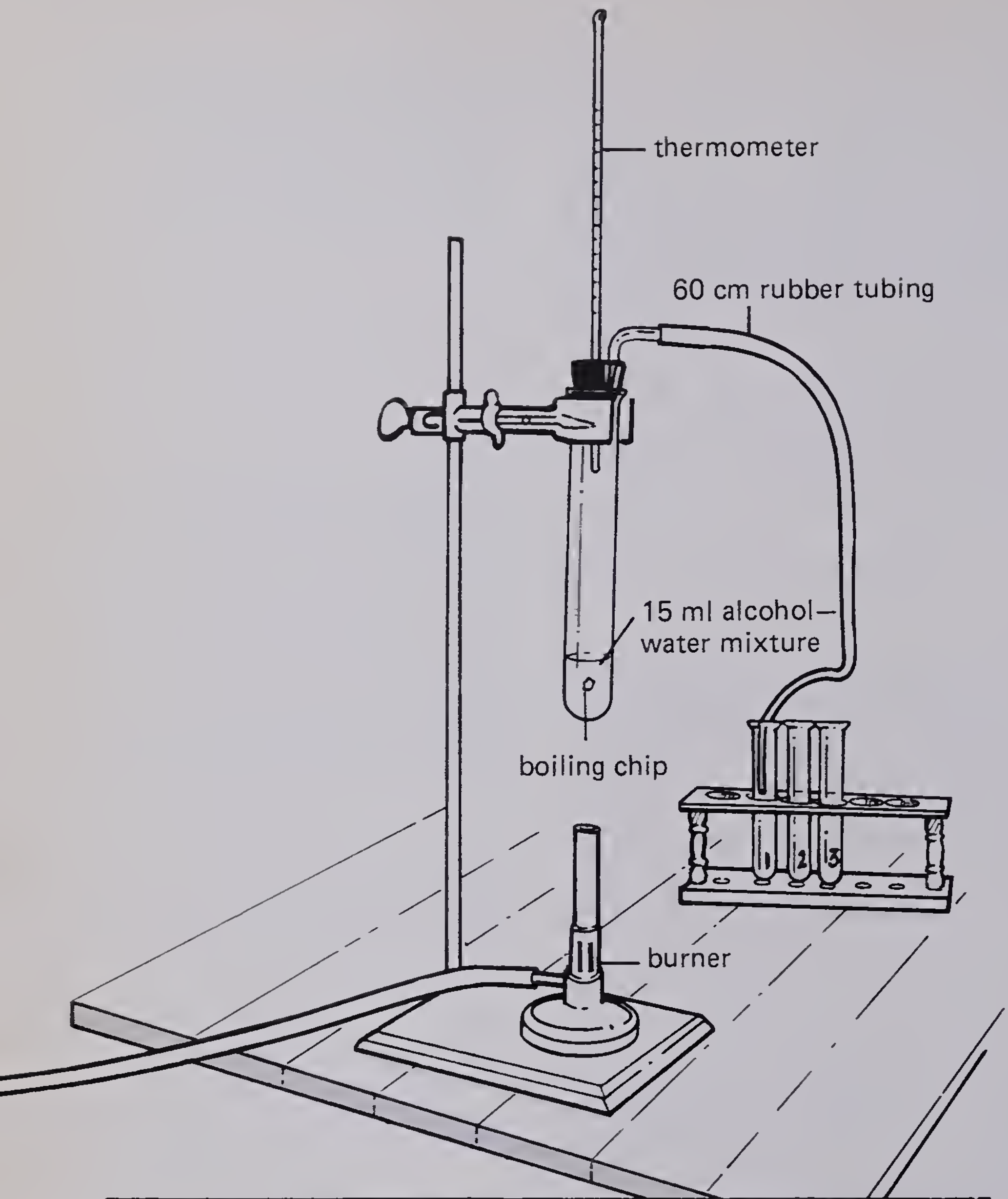
Fractional distillation is one part of the refining process.

A boiling chip facilitates smooth boiling.

You might want to have the entire ring stand, test tube, and stopper assembly available.

If it is available, you may want to use a small distilling flask and condenser.

Keep the stock alcohol solution away from open flames.



A. Put 15 ml of the isopropyl alcohol—water mixture into the large test tube. Put the test tube into the clamp on the ring stand as shown.

B. Add a boiling chip to the test tube. Carefully insert the delivery assembly. Put the rubber tubing on the glass tube.

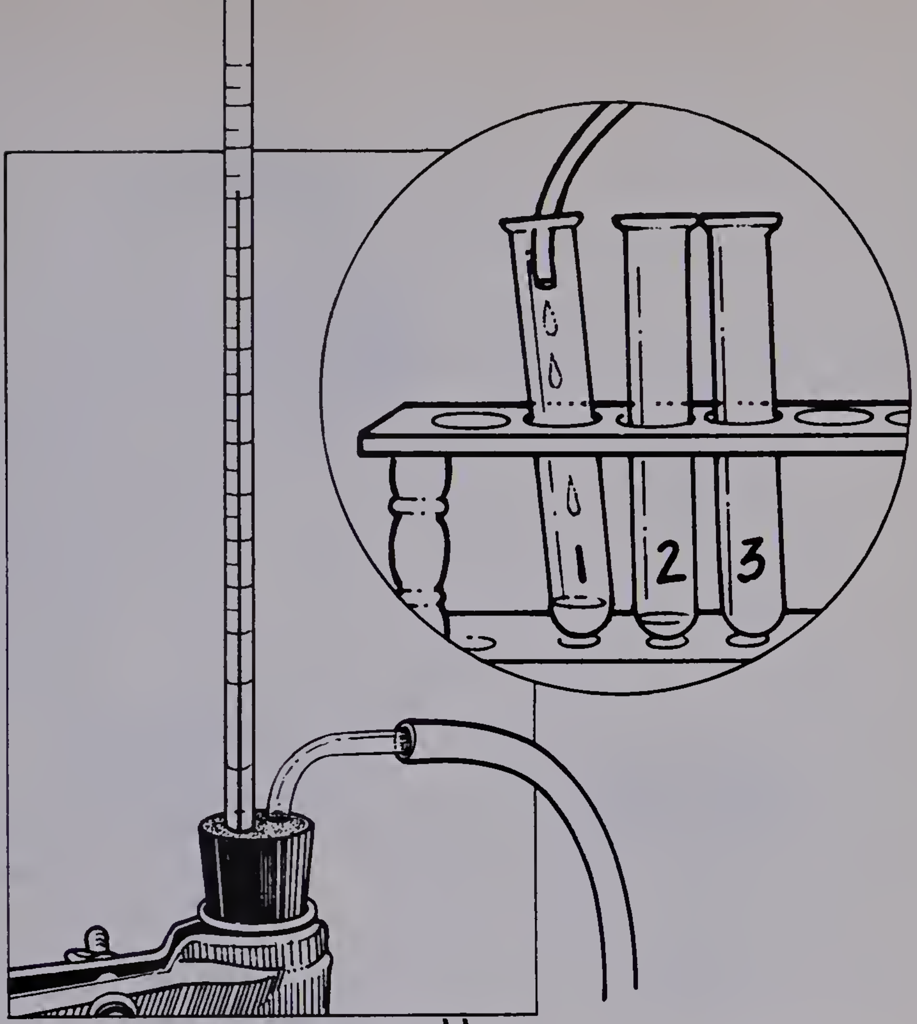
C. With a grease pencil, label three medium test tubes *1, 2,* and *3*. Place them in order in a test-tube rack. Put the tubing from the large test tube into Test Tube 1. Be sure to keep the test-tube rack as far as possible from the burner.

D. Light the burner. With a low flame, gently heat the large test tube by moving the flame back and forth underneath it. Heat the mixture until it begins to boil gently.

As the liquid boils, the temperature will stay steady somewhere around 82°C. The liquid boils out of the large test tube, condenses in the rubber hose, and drips into Test Tube 1. After a little while, the collection of liquid in Test Tube 1 will slow down.

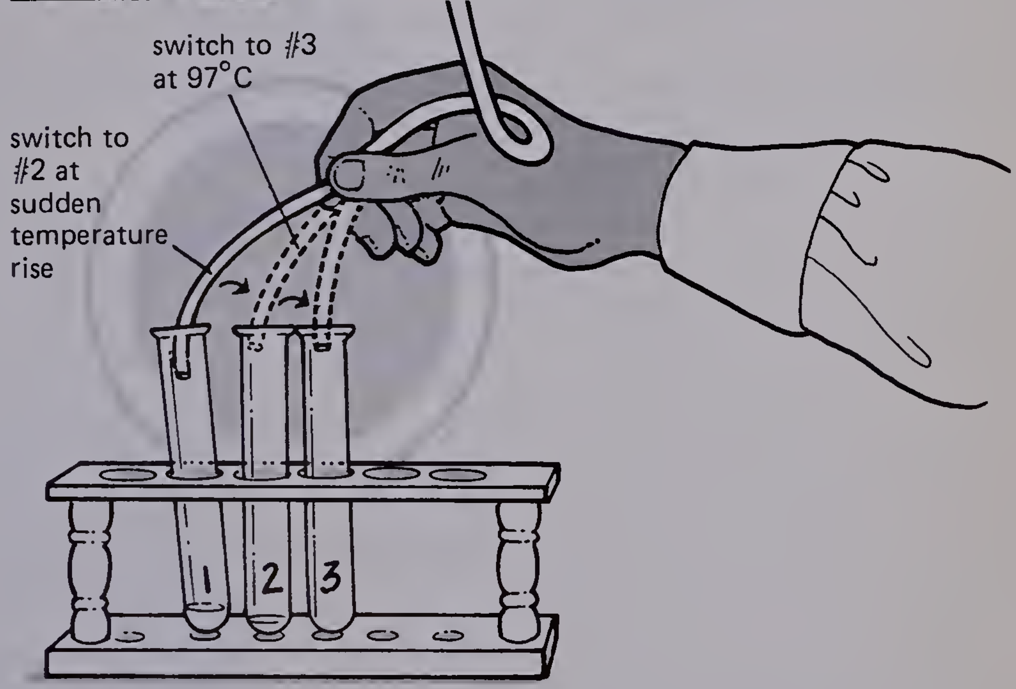
At high altitudes, temperatures will be lower than noted here. You will need to establish the temperatures that should be used by your students.

E. Check the temperature when you begin getting drops of liquid in Test Tube 1. It should stay steady.



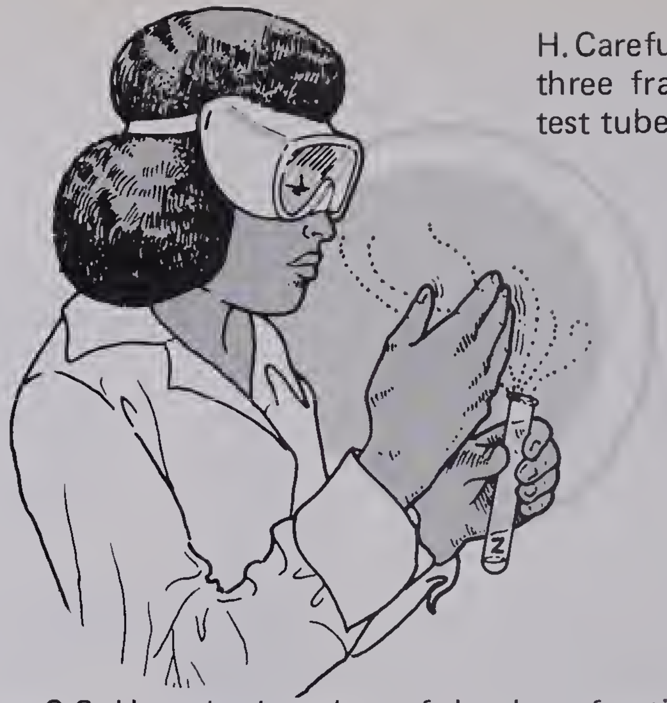
F. When the temperature starts to rise suddenly, quickly transfer the tubing to Test Tube 2. (Be careful; the tubing is hot!)

G. Continue heating the mixture gently until the thermometer reads about 97°C. Then, carefully transfer the tubing to Test Tube 3. Continue heating the mixture until only a few millilitres of liquid remain in the large test tube. But don't let all the liquid boil out. Turn off the burner before that happens.


switch to #3 at 97°C
switch to #2 at sudden temperature rise
1
2
3

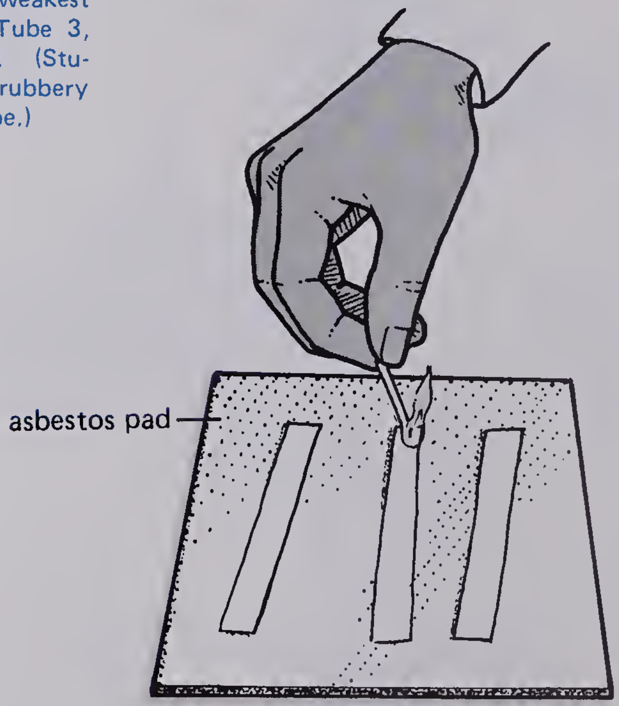
You have now completed a fractional distillation of the isopropyl alcohol—water mixture. There are three parts, or *fractions*, of the mixture in Test Tubes 1, 2, and 3. Now you'll want to see how these fractions are different from the original mixture.

H. Carefully smell each of the three fractions in the medium test tubes, as shown.



- 3-2. How do the odors of the three fractions compare?

3-2. The fraction in Test Tube 1 has the strongest odor because it's mostly alcohol. The weakest odor comes from Test Tube 3, which has mostly water. (Students may also notice a rubbery odor from the delivery tube.)



I. Test each of the fractions to find out whether one burns more easily than the others. Dip a strip of paper into each liquid. Put the strips on the asbestos pad. Then try to light the wet end of the strips with a match.

- 3-3. How do the fractions compare in their burning behavior?

3-3. The fraction from Test Tube 1 burns easily. The fraction from Test Tube 2 burns less easily. The fraction from Test Tube 3 won't burn.

Each fraction you collected has properties different from the other fractions and from the original mixture. The fraction in Test Tube 1 is almost pure isopropyl alcohol. The fraction in Test Tube 3 is almost pure water. Test Tube 2 contains a mixture of alcohol and water.

If you ran these fractions through the fractional distillation process several more times, you could get the alcohol and water separated even better. That's what's done in the fractional distillation of crude oil. Look at Figure 3-2 below.

Just like alcohol and water, the different hydrocarbons in crude oil have different boiling points. Each changes to a vapor at a different temperature.

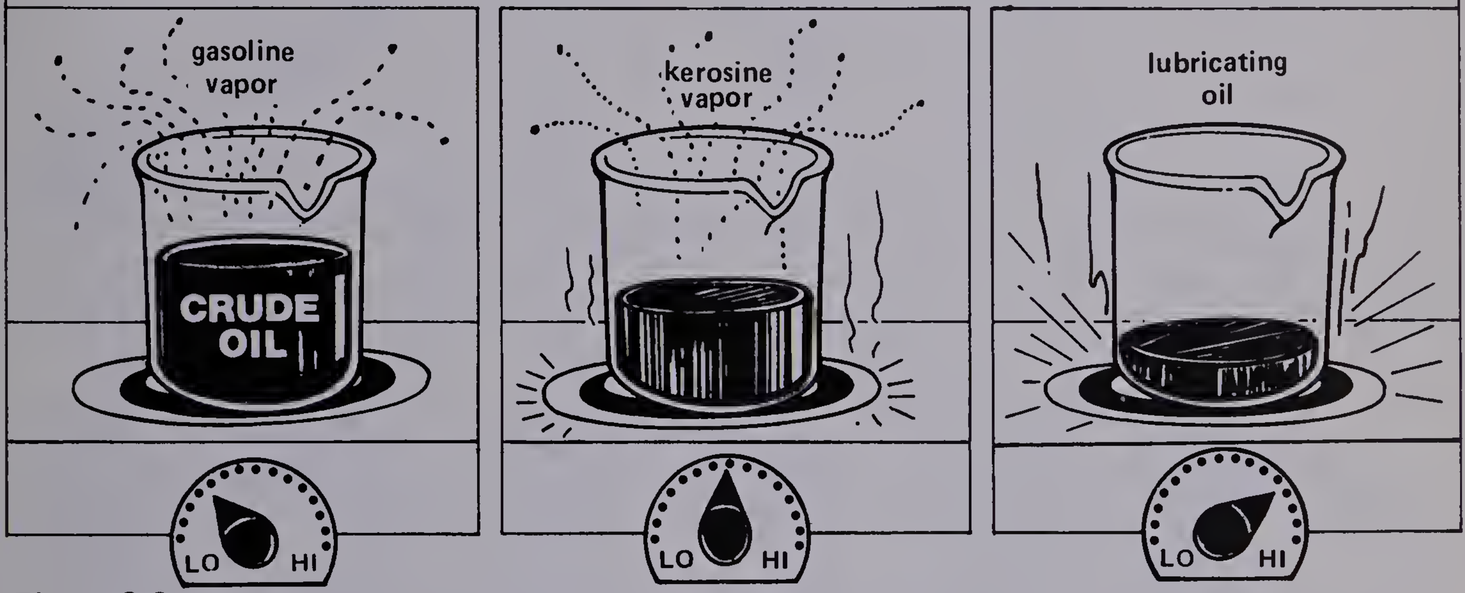


Figure 3-2

☆ 3-4. What happens during the fractional distillation of a liquid mixture?

3-4. Different parts (fractions) boil off at different temperatures and are collected separately.

In the early days of oil refining, the separation process was done by heating the crude oil in a tank and distilling by fractions. But this was too slow a method where very large quantities were involved. So modern processes, like the one shown in Figure 3-3 below, use fractional distillation columns.

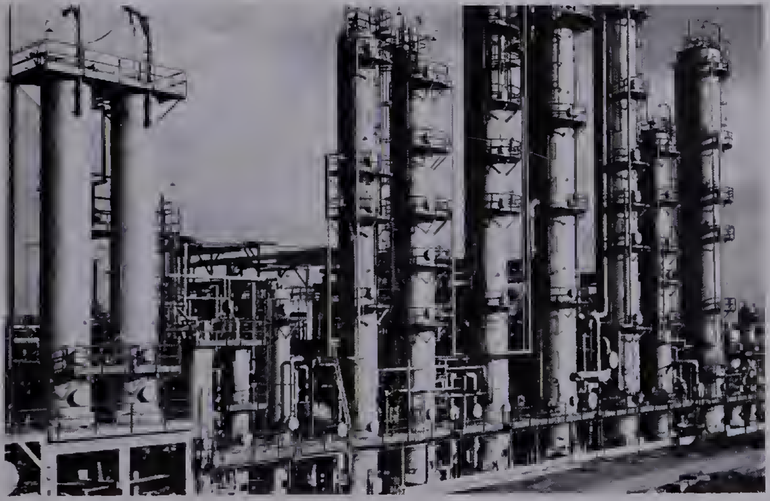
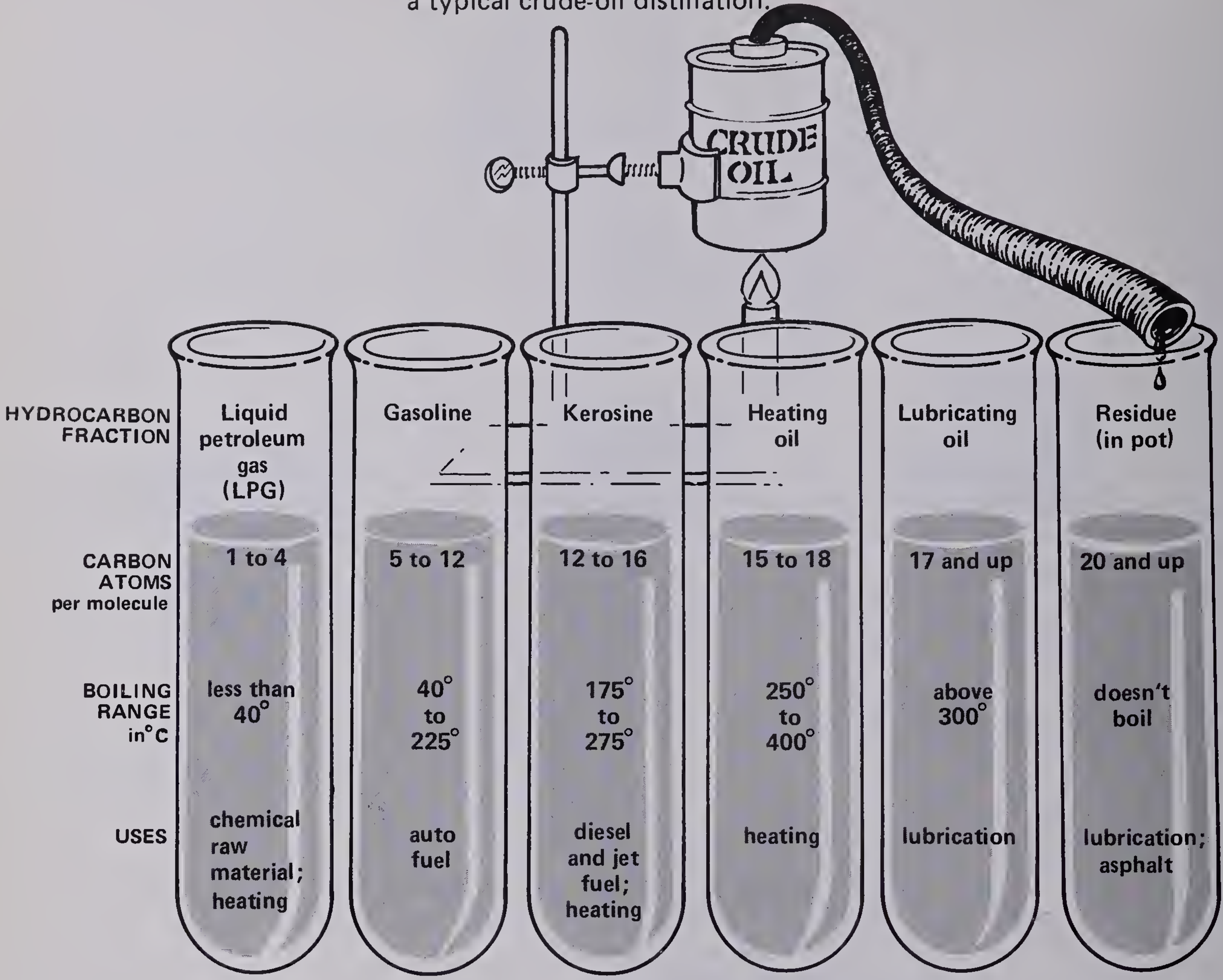


Figure 3-3

Figure 3-4 below shows the hydrocarbon fractions obtained in a typical crude-oil distillation.



HYDROCARBON FRACTION	Liquid petroleum gas (LPG)	Gasoline	Kerosine	Heating oil	Lubricating oil	Residue (in pot)
CARBON ATOMS per molecule	1 to 4	5 to 12	12 to 16	15 to 18	17 and up	20 and up
BOILING RANGE in°C	less than 40°	40° to 225°	175° to 275°	250° to 400°	above 300°	doesn't boil
USES	chemical raw material; heating	auto fuel	diesel and jet fuel; heating	heating	lubrication	lubrication; asphalt

Figure 3-4

☆ 3-5. How does fractional distillation separate the different hydrocarbons in crude oil?

3-5. As the crude oil is heated, the different substances boil off and are collected at different temperatures, in the order shown in Figure 3-4.

Between twenty and thirty percent of a barrel of crude oil will distill out as gasoline. But this "straight run" gasoline isn't good enough for use in modern engines. Furthermore, almost half the total demand for crude oil products is for gasoline — so fractional distillation could never produce enough.

How have oil companies coped? They are finding ways to make more and better gasoline from crude oil. *Catalytic cracking* is one such way.

Heat and pressure can *crack* bigger kerosine and heating oil molecules into smaller gasoline molecules, but not fast enough. A *catalyst*, which speeds up the breaking, is added. That's what catalytic cracking is. This process produces more and better gasoline than distilling does. Look at Figure 3-5 below.

Fractions may also be thermally cracked without catalysts and polymerized with catalysts to form gasolines. Three other methods used today that alter the structure of the gasoline hydrocarbons are alkylation, isomerization, and catalytic re-forming.

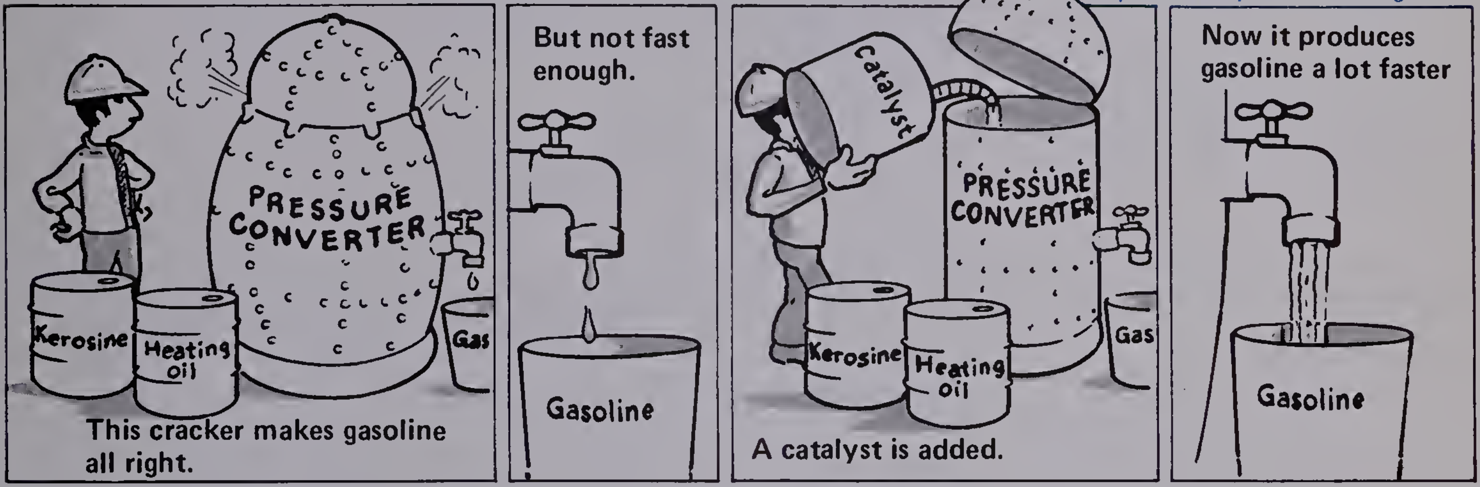


Figure 3-5

☆ 3-6. What is *cracking*? What does the catalyst do in catalytic cracking?

3-6. Cracking is breaking larger kerosine and heating oil molecules into gasoline molecules. The catalyst speeds up the cracking process.

The gasoline in your car is a blend. It contains straight-run (distilled) gasoline and gasolines made by catalytic cracking and other methods. It also contains chemical additives. These improve the fuel's performance in your engine.

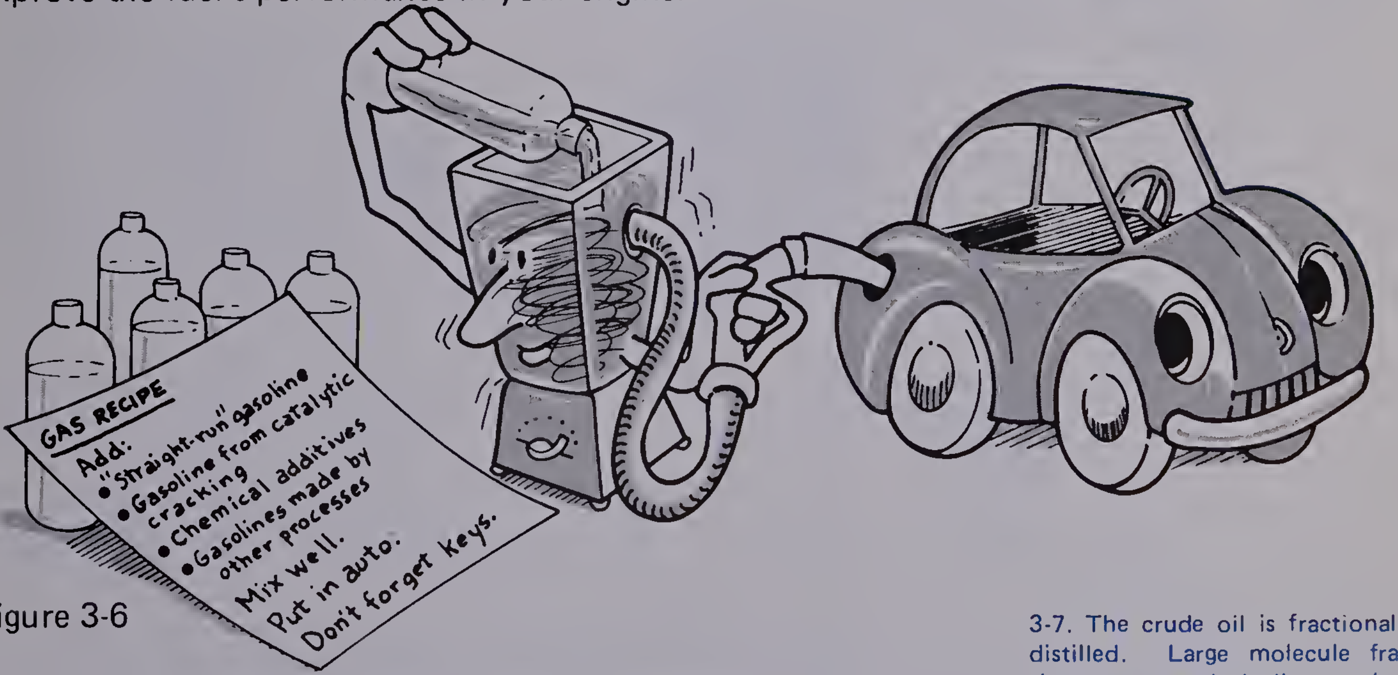

GAS RECIPE
Add:
• "Straight-run" gasoline
• Gasoline from catalytic cracking
• Chemical additives
• Gasolines made by other processes
Mix well.
Put in auto.
Don't forget keys.

Figure 3-6

☆ 3-7. What are three processes used in producing gasoline for your car?

3-7. The crude oil is fractionally distilled. Large molecule fractions are catalytically cracked. Gasolines and additives from various processes are blended.

ACTIVITY EMPHASIS: Carbon dioxide and water are the main products of burning fossil fuels. Particulates, sulfur oxides, nitrogen oxides, carbon monoxide, and unburned hydrocarbons are other products.

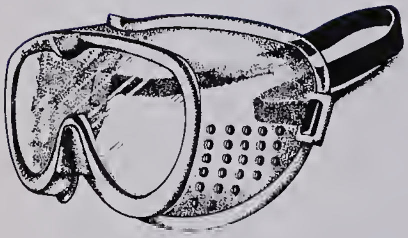
MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

ACTIVITY 4: INVISIBLE PRODUCTS

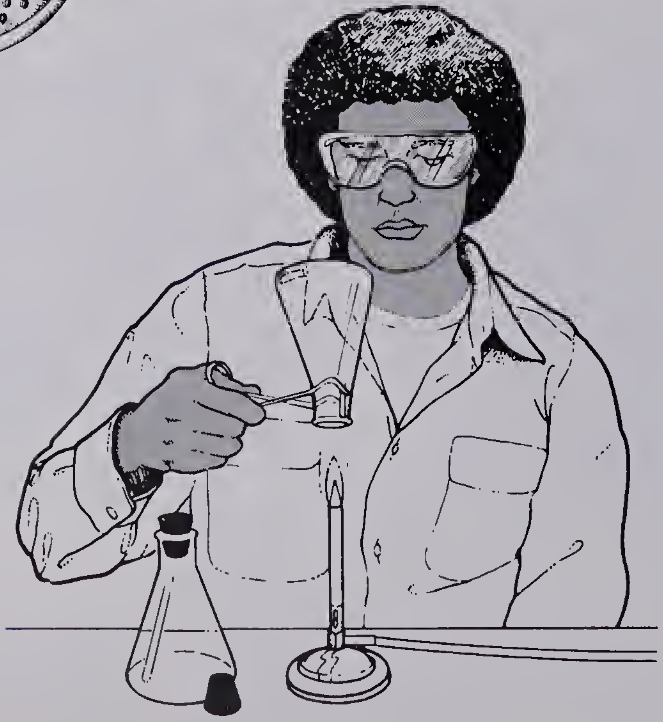
If you've ever seen a burning gas flame, you may remember seeing colors and waves and feeling the heat. But there were other things coming from that flame. To find out about the major invisible products of burning fuels, you will need about thirty minutes and these materials.

safety goggles
Bunsen burner or propane torch
2 small beakers or baby-food jars
15 ml clear limewater
small graduated cylinder
2 dry, 250-ml Erlenmeyer flasks
aluminum-foil square, 6 cm X 6 cm
2 strips cobalt chloride test paper
tongs
2 solid stoppers to fit flasks
pencil
soda straw

If you need help with adjusting a burner, read "Resource Unit 17: Using a Burner" now. Then begin Step A.



CAUTION	Remember to wear your safety goggles.

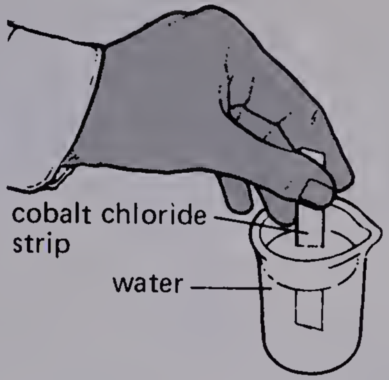


A. Light the burner or torch and adjust the flame to the hot (pale blue) color. Using the tongs, hold the open end of one dry flask over the flame for about 15 seconds.

B. Remove the flask, and quickly stopper it. Set the flask aside to cool. Do the same thing again for the second flask. Then turn off the burner.

While the flasks are cooling, let's look at two tests you can use to find out what substances are in the flasks.

C. Get one strip of dry cobalt chloride test paper. Note its color. Then, dip it into a beaker of water.

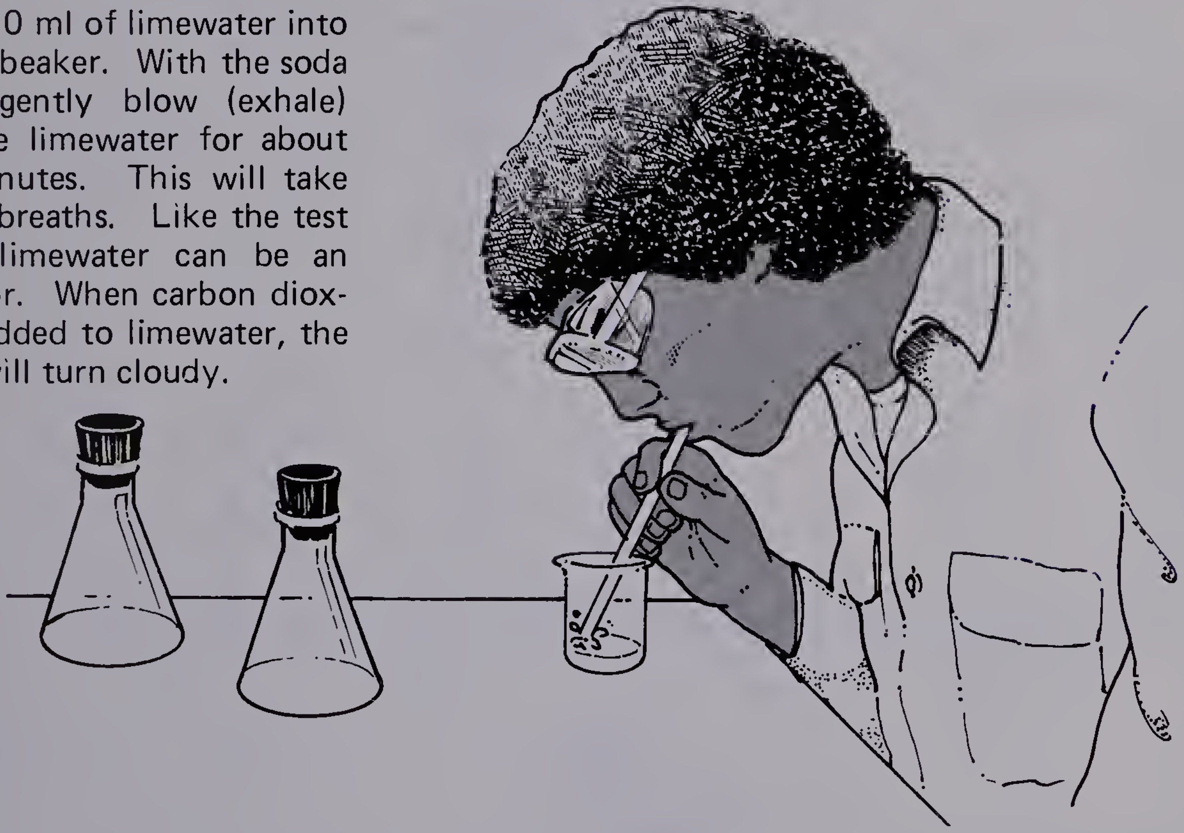


- 4-1. What happens to the color of cobalt chloride test paper when the paper is wet with water?

4-1. It changes from blue to pink.

If you're not sure how to measure liquids, read "Resource Unit 5: Measuring Volume" now. Then do Step D.

D. Put 10 ml of limewater into a small beaker. With the soda straw, gently blow (exhale) into the limewater for about two minutes. This will take several breaths. Like the test paper, limewater can be an indicator. When carbon dioxide is added to limewater, the liquid will turn cloudy.



- 4-2. What happened when you blew into the limewater? Why?

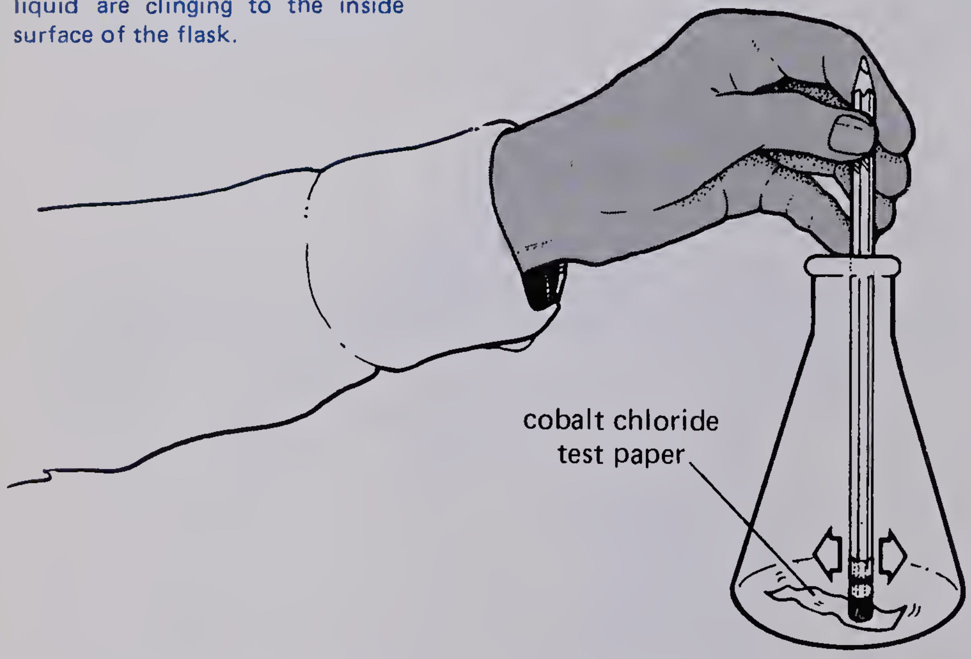
4-2. The limewater turned cloudy because of the carbon dioxide in the exhaled air.

It turns out that carbon dioxide, CO_2, which you exhale, is the only common gas that turns limewater cloudy. Now you have two identification tests. Use them to help identify the products of the burning gas that you collected in the flasks.

E. Carefully look at one of the cooled, stoppered flasks.

4-3. Some small droplets of clear liquid are clinging to the inside surface of the flask.

- 4-3. Describe what you see inside the flask.



F. Remove the stopper from the flask. Insert a piece of cobalt chloride test paper. Use the pencil to rub the paper on the droplets of clear liquid. Observe the color of the paper.

4-4. Water; from the burner flame

- 4-4. What is the liquid in the flask? Where did it come from?

G. Measure out 5 ml more of limewater. Remove the stopper from the other flask and quickly add the limewater. Replace the stopper, and shake the flask.

● 4-5. What does the flask contain? Where did this product come from?

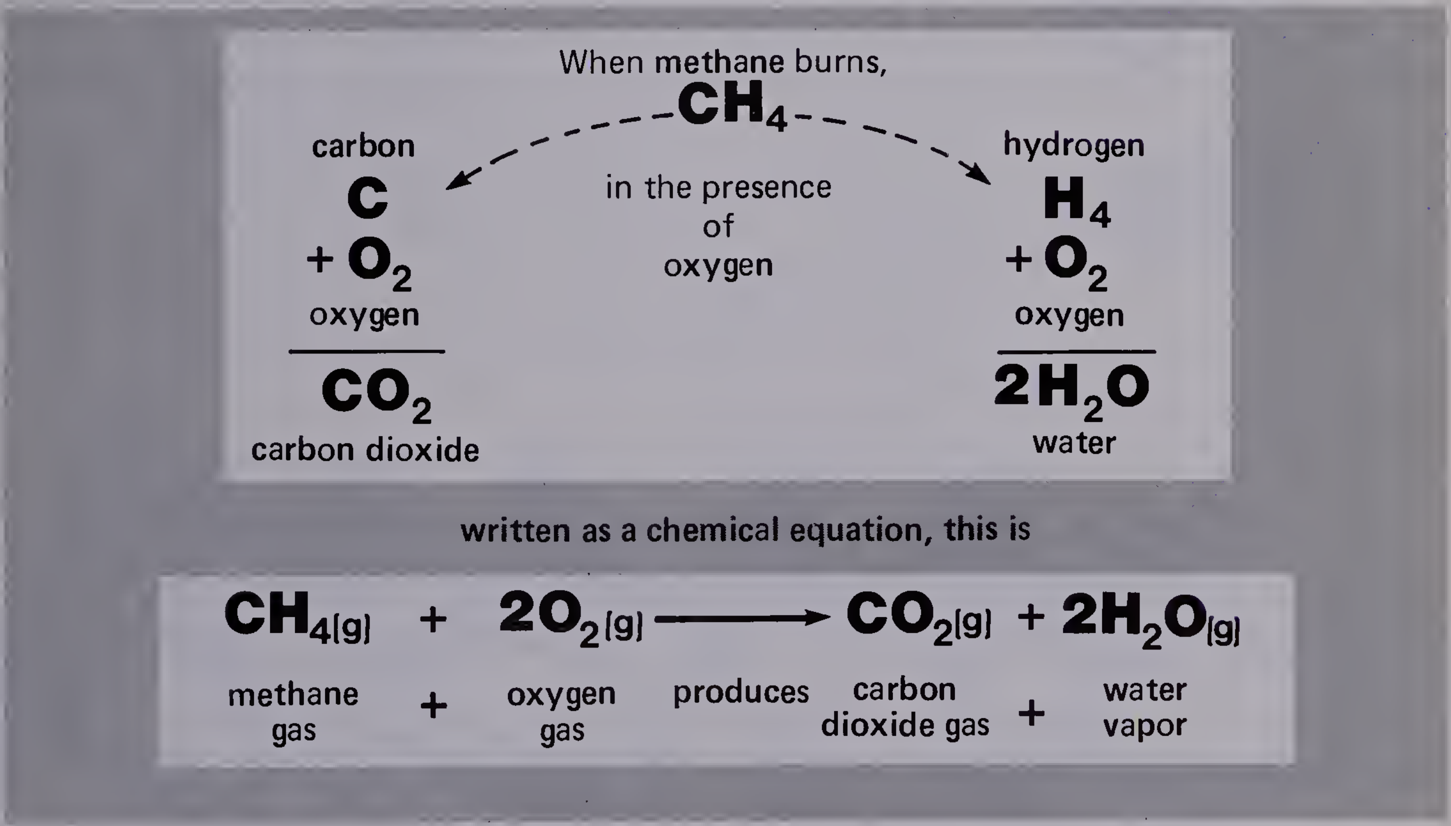
4-5. Carbon dioxide; from the burner flame

The gas you burned in your investigation was probably natural gas. But it could have been another fossil fuel like LPG (liquid petroleum gas) or propane. The results would have been the same. The burning of any fossil fuel — even gasoline, heating oil, or coal — mainly produces carbon dioxide, CO_2, and water, H_2O.

☆ **4-6. What are the two major products of burning fossil fuels?**

4-6. Carbon dioxide and water

Natural gas is composed mostly of methane, CH_4, the simplest hydrocarbon. With enough oxygen present, the carbon and hydrogen atoms combine with oxygen atoms to form carbon dioxide and water molecules. Look at Figure 4-1 below. It shows what happens when methane burns. (If you need help understanding the formula, read "Resource Unit 22: Chemical Shorthand.") If there's enough oxygen around, any fossil fuel reacts this same way.



written as a chemical equation, this is

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

methane gas + oxygen gas produces carbon dioxide gas + water vapor

Figure 4-1

☆ **4-7. When a fossil fuel burns, what happens to the carbon atoms in it? What happens to the hydrogen atoms?**

4-7. Both the carbon and the hydrogen atoms combine with oxygen atoms.

Fossil fuels are made mostly of carbon and hydrogen atoms. But they also contain impurities consisting of other elements. These impurities can also combine with oxygen when the fuel is burned. The amount of impurities varies from fuel to fuel. Natural gas generally has the fewest and coal the most.

As a safety precaution, a trace of a sulfur compound (a mercaptan) is added to natural gas, giving it a recognizable odor.

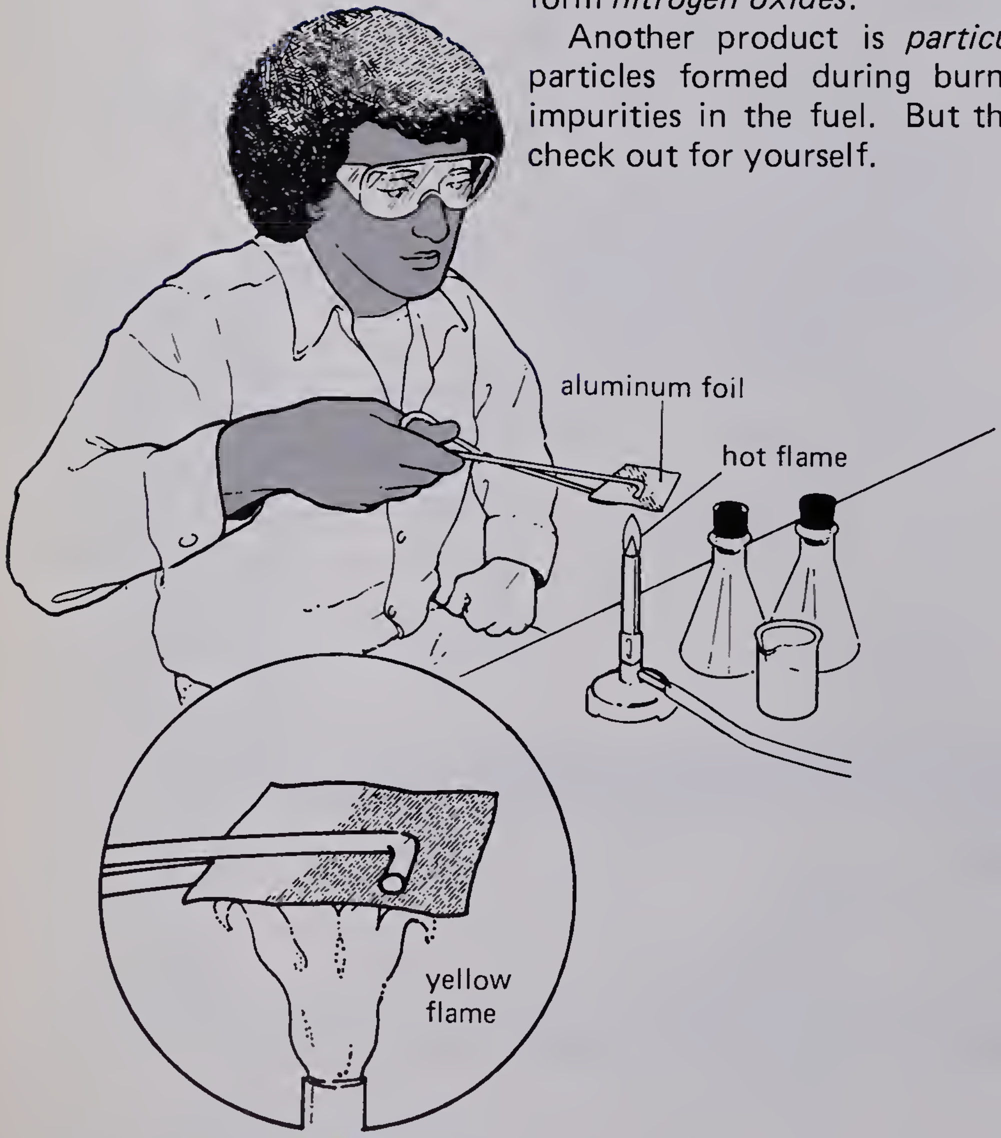
But the same fossil fuel may vary in impurities depending on where it comes from. Some coal has much less sulfur than other coal, producing less *sulfur oxides* when burned.

4-8. Sulfur oxides

- 4-8. Besides carbon dioxide and water, what product is formed when sulfur-bearing fossil fuels are burned?

When fossil fuels burn at high temperatures, another product can appear. Nitrogen molecules in the air react with oxygen to form *nitrogen oxides*.

Another product is *particulates* — different kinds of solid particles formed during burning. Some particles come from impurities in the fuel. But there's another source that you can check out for yourself.



4-9. A black material collected on the aluminum when it was held in the yellow flame.

H. Light the burner again. Make sure you have a blue flame. Using the tongs, hold the aluminum-foil square in the flame for a few seconds. Remove the square, and look at it.

I. Now adjust the air supply to get a yellow flame. Turn the aluminum foil over. Hold it in the yellow flame for a few seconds. Remove the square, and look at it.

- 4-9. What new thing happened in Step I?

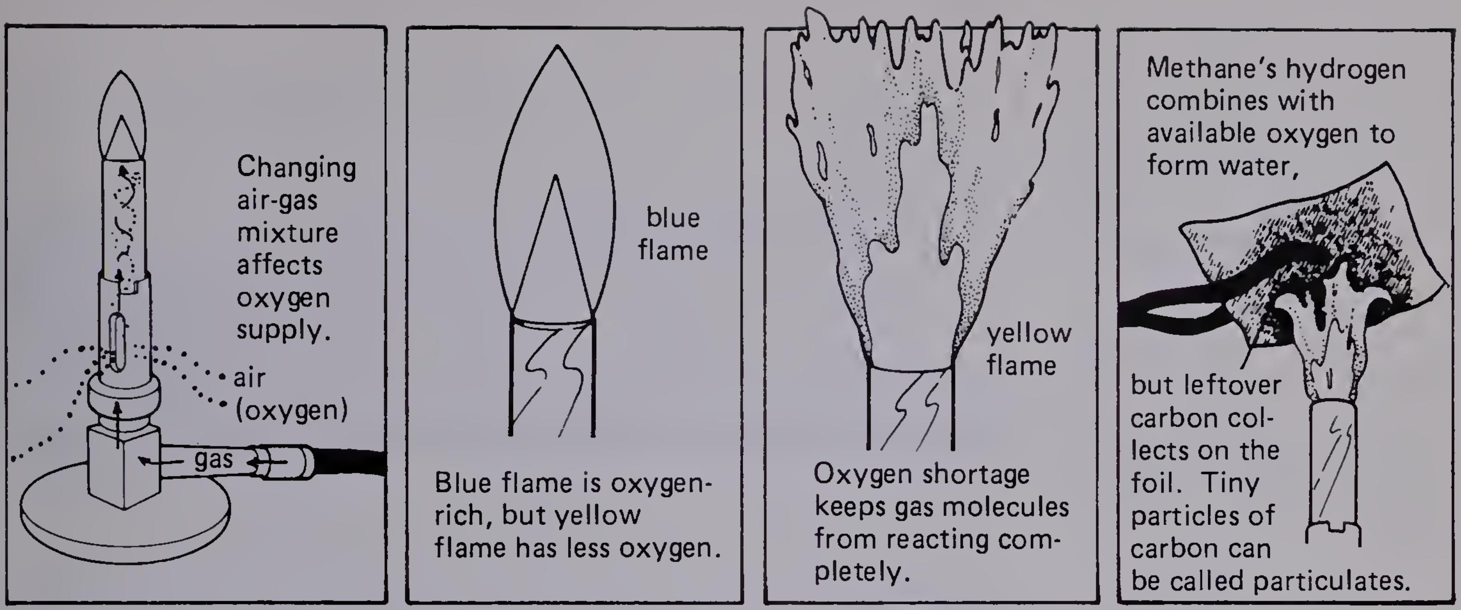

Changing air-gas mixture affects oxygen supply.
air (oxygen)
gas
blue flame
Blue flame is oxygen-rich, but yellow flame has less oxygen.
yellow flame
Oxygen shortage keeps gas molecules from reacting completely.
Methane's hydrogen combines with available oxygen to form water,
but leftover carbon collects on the foil. Tiny particles of carbon can be called particulates.

Figure 4-2

● 4-10. When you burn a fossil fuel, what are two possible causes of particulates?

4-10. Burning with not enough oxygen and burning impurities in the fuel

Two other products can result when a burning fossil fuel lacks enough oxygen. One is carbon monoxide, CO, a deadly gas. It forms when coal or charcoal is burned in limited oxygen. The other product is unburned hydrocarbons. These are pieces of large molecules — like those of gasoline — that didn't get to react with oxygen during the burning of the fuel.

People burn fuels mainly to get energy, and they do get it. But people should also be aware of what else they're getting. Figure 4-3 below summarizes this information.

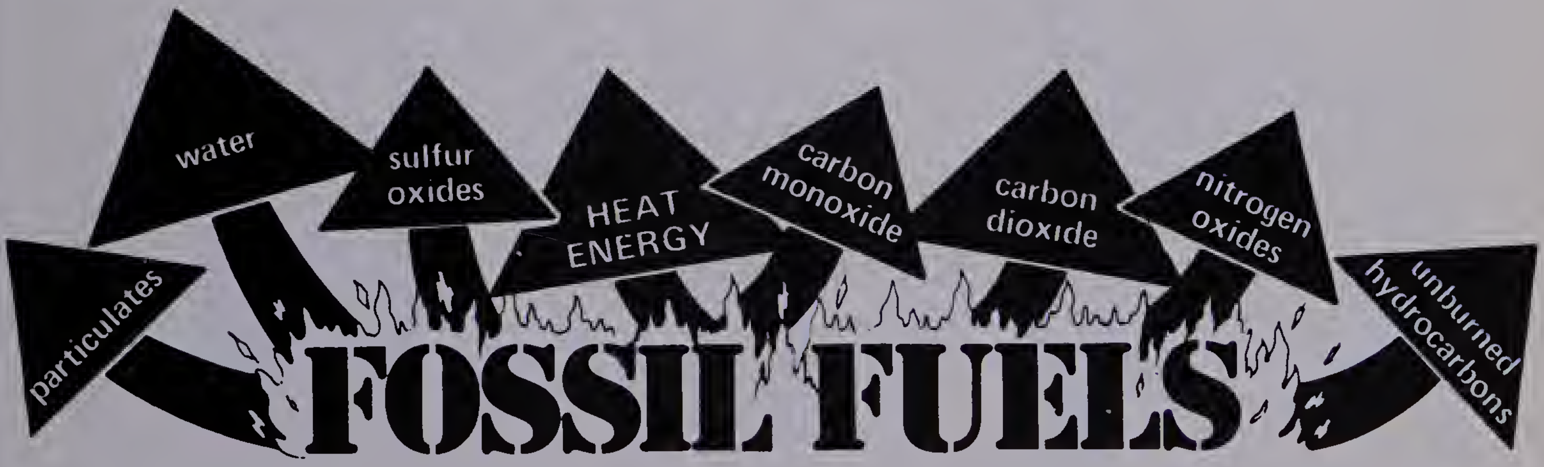


Figure 4-3

☆ 4-11. Other than heat energy, what products can result from the burning of fossil fuels?

4-11. Carbon dioxide, water, sulfur oxides, carbon monoxide, particulates, nitrogen oxides, and unburned hydrocarbons

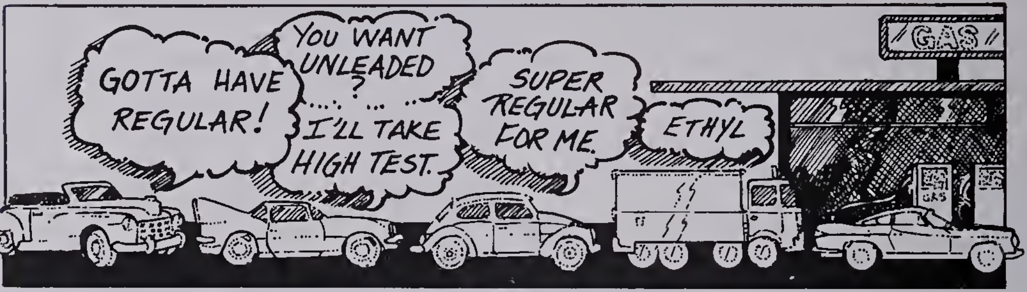
ACTIVITY 5: WHEN GASOLINE BURNS

ACTIVITY EMPHASIS: Of two gasolines, the one with the higher octane number will burn more evenly and less explosively, thus having greater knock resistance. Tetraethyllead is added to most premium and regular gasolines to improve knock resistance. Amounts of branched-chain hydrocarbons may be increased in unleaded gasolines.

MATERIALS PER STUDENT LAB GROUP: None

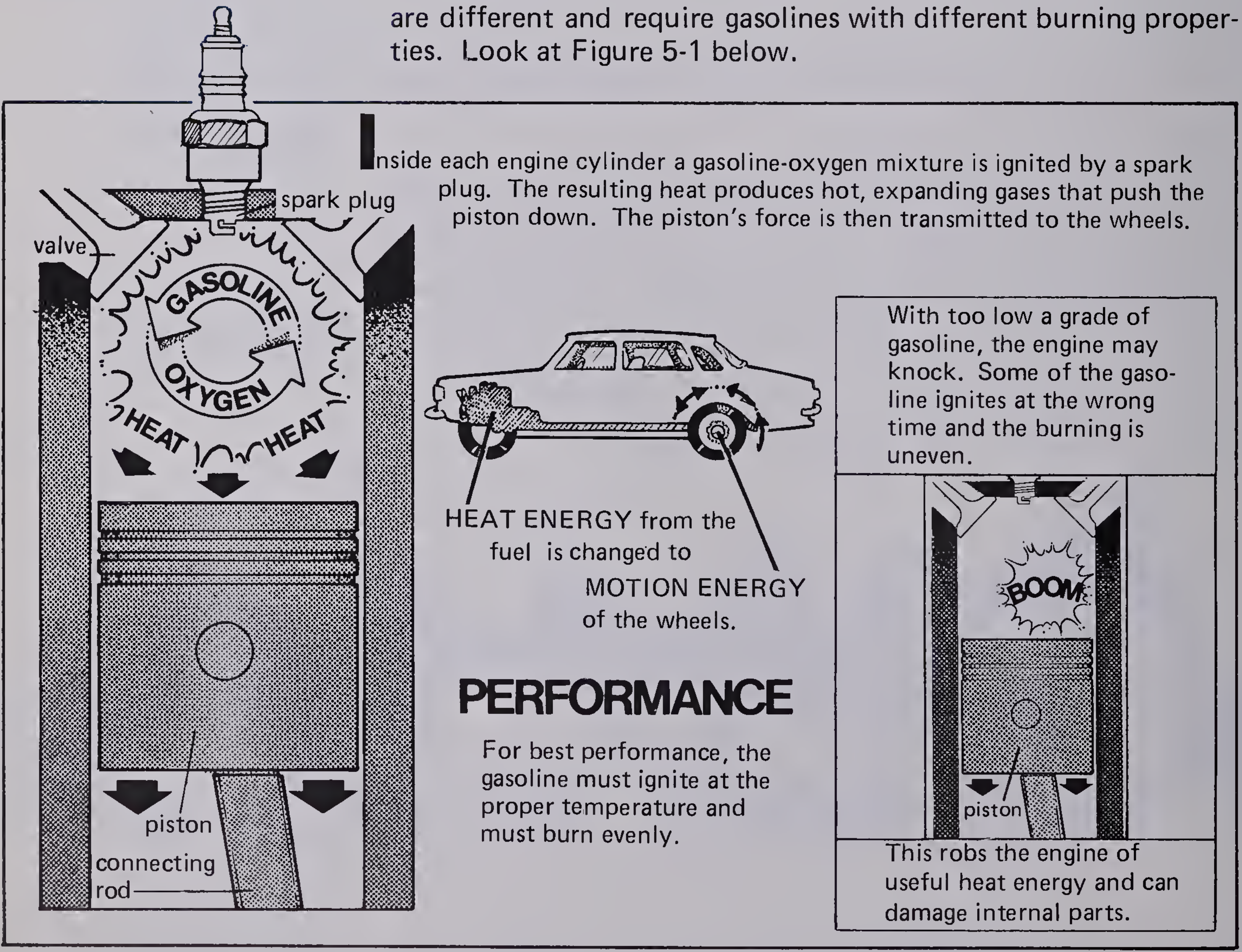
5-1. [Answers will vary. Some possibilities are regular, ethyl, unleaded, high test, low octane, and premium.]

When you drive into a service station for gasoline, you usually have a choice. Most stations offer several different grades.


GOTTA HAVE REGULAR!
YOU WANT UNLEADED?
.... I'LL TAKE HIGH TEST.
SUPER REGULAR FOR ME.
ETHYL
GAS

- 5-1. List some of the different grades of gasoline.

Gasoline comes in several grades because automobile engines are different and require gasolines with different burning properties. Look at Figure 5-1 below.



Inside each engine cylinder a gasoline-oxygen mixture is ignited by a spark plug. The resulting heat produces hot, expanding gases that push the piston down. The piston's force is then transmitted to the wheels.

For best performance, the gasoline must ignite at the proper temperature and must burn evenly.

With too low a grade of gasoline, the engine may knock. Some of the gasoline ignites at the wrong time and the burning is uneven.

This robs the engine of useful heat energy and can damage internal parts.

Figure 5-1

● 5-2. The gasoline in a car ought to burn evenly. Why is that important?

5-2. To avoid wasting energy and damaging engine parts

● 5-3. What causes engine knock?

5-3. Gasoline that ignites at the wrong time, causing uneven burning

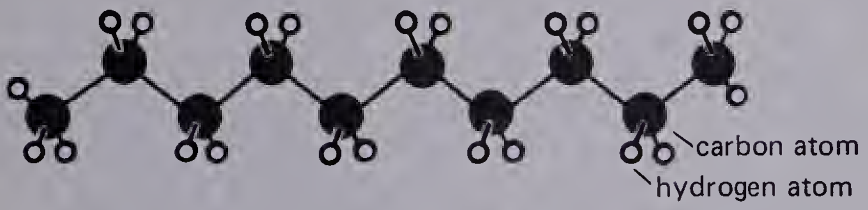
To even out the burning and prevent knocking, different substances are often added to the gasoline. Many brands use an antiknock substance called *tetraethyllead* (ethyl). The more tetraethyllead a gasoline has, the better it resists knocking.

☆ **5-4. Premium gasoline contains more tetraethyllead than regular gasoline. Which gasoline is more resistant to knocking? Why?**

5-4. Premium gasoline is more knock resistant. With more tetraethyllead, it burns more evenly than regular gasoline.

Another way to help solve the knocking problem is to increase the amount of what are called *branched-chain hydrocarbon molecules* in the gasoline. Ordinary gasolines normally consist mainly of *straight-chain molecules*. Figure 5-2 below shows the difference.

STRAIGHT-CHAIN HYDROCARBON MOLECULE



BRANCHED-CHAIN HYDROCARBON MOLECULE

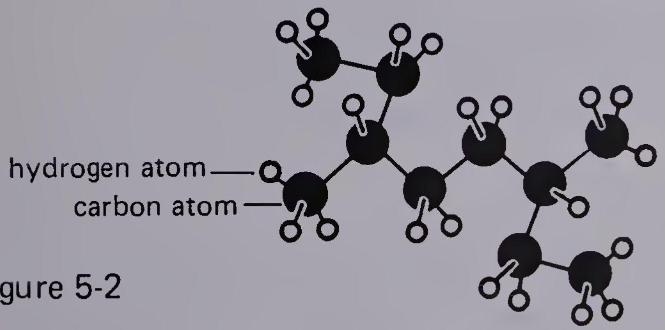


Figure 5-2

● 5-5. How is a branched-chain hydrocarbon molecule different from a straight-chain molecule? (Hint: Look at the number of other carbon atoms that each carbon is joined to.)

5-5. In a branched-chain molecule, some carbon atoms are connected to three other carbon atoms, rather than two.

Branched-chain molecules cause less knocking than straight-chain molecules because they burn more evenly. Part of the reason for this even burning has to do with the carbon atoms at the ends of molecule branches.

Oxygen molecules can get to end carbon atoms and react with them (burn). Inside carbon atoms burn later. Since a branched-chain molecule has more end carbon atoms, more of them will burn at about the same time. The burning is more even.

5-6. Tetraethyllead and branched-chain hydrocarbon molecules

☆ 5-6. What two additives are used in gasoline to help make it more resistant to knocking?

A very good nonknocking gasoline is *isooctane* [ice-oh-OCK-tane], diagrammed in Figure 5-3 below.

ISOOCTANE

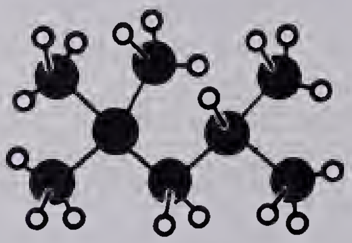


Figure 5-3

Pure isooctane is used as the standard for octane rating — its octane number is 100. Other automobile gasolines and blends are assigned octane numbers up to 100, depending on the way they burn in a test engine. The more a gasoline or blend burns like isooctane, the higher its octane number.

Additives like tetraethyllead affect the burning rate. This is reflected in the octane number. Knock-resistance and high octane rating go together. Look at the table in Figure 5-4 below.

See "Background Information" in ATE front matter (page ATE 10) for more about octane numbers. Activity 6, page 29, explains why unleaded gasoline, despite its lower octane number, is used in new cars.

GASOLINE GRADE	TETRAETHYL-LEAD?	AVERAGE OC-TANE NUMBER
Premium	yes	95.5
Regular	yes	90.0
Unleaded	no	88.0

Figure 5-4

5-7. Premium

☆ 5-7. Which grade of gasoline burns most like isooctane?

Most American cars sold since 1975 are equipped with catalytic converters that require unleaded gasoline. So unleaded gasoline usually has some branched-chain hydrocarbon molecules blended in. They can raise the octane number enough to prevent engine knock.

But branched-chain molecules are more expensive to produce than tetraethyllead. Thus unleaded gasoline tends to cost more than leaded gas with the same octane rating.

5-8. Try using a higher-octane blend.

● 5-8. Suppose you are using 90-octane gasoline in your car and are experiencing engine knock. What's one thing you could try?

ACTIVITY 6: IT'S EXHAUSTING!

ACTIVITY EMPHASIS: In cars without catalytic converters, burning gasoline with lead produces six air pollutants. In cars with converters, burning unleaded gasoline produces one pollutant.

MATERIALS PER STUDENT LAB GROUP: None

Gasoline is a fossil fuel. So burning it forms a number of products. And gasolines contain additives that also burn. Unless something is done, these products will be emitted from the car's exhaust. Look at Figure 6-1 below.

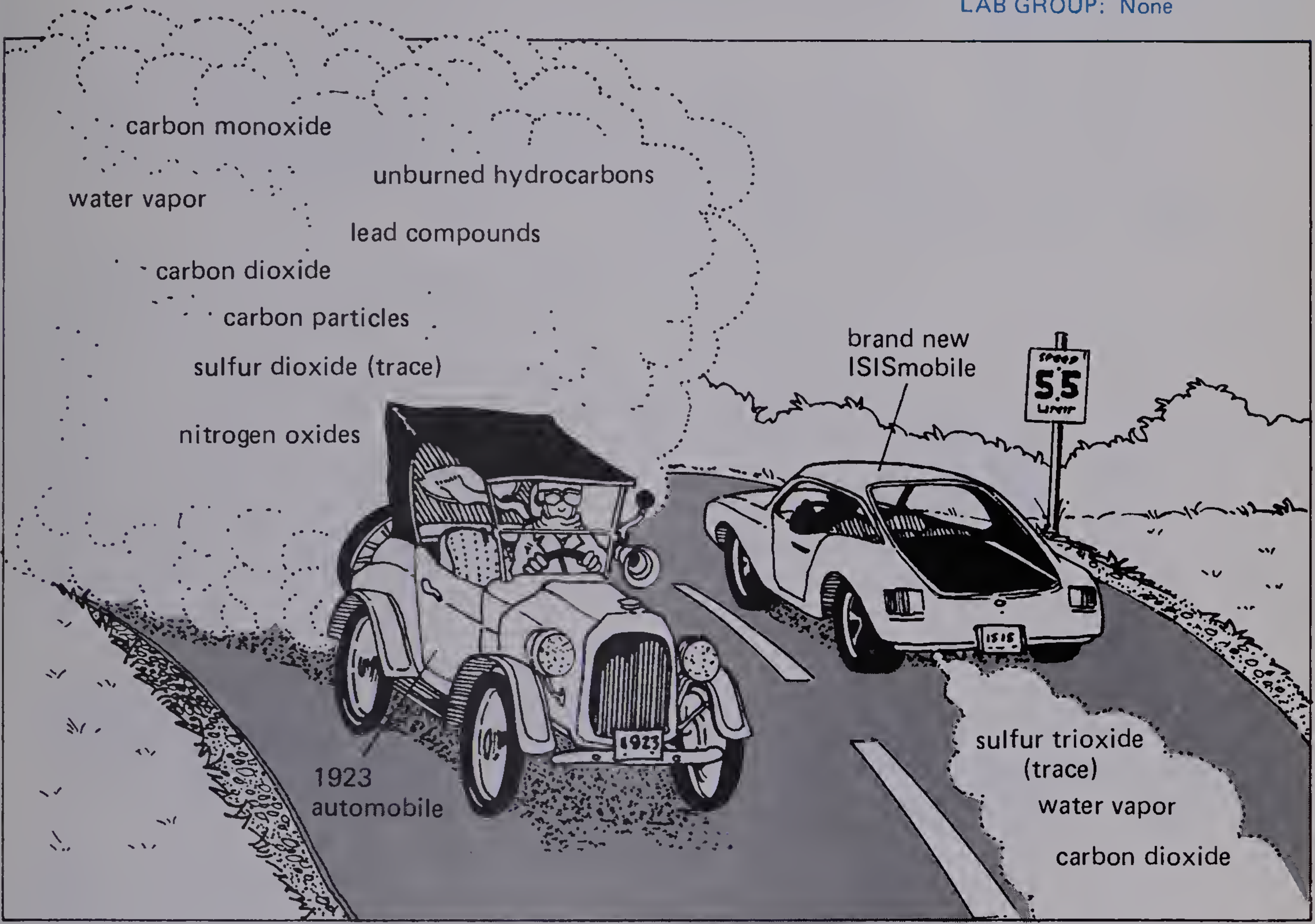
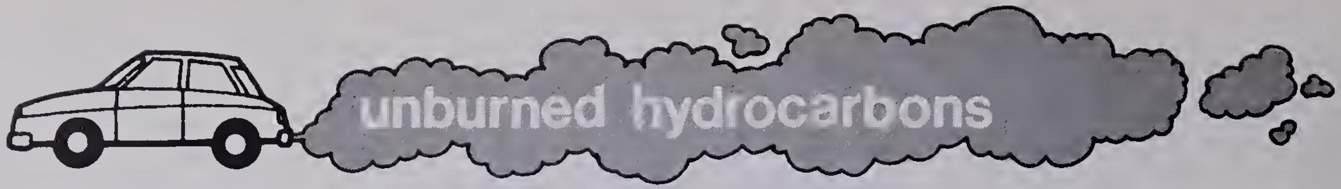


Figure 6-1

● 6-1. In Figure 6-1 above, what exhaust emissions from the 1923 car would you call pollutants? How about from the ISISmobile?

6-1. The pollutants from the old car are unburned hydrocarbons, carbon particles, carbon monoxide, sulfur dioxide, nitrogen oxides, and lead compounds. The pollutant from the new car is sulfur trioxide.

Water and carbon dioxide might not be considered pollutants. After all, you breathe them from your own lungs. (It's worth mentioning, though, that carbon dioxide is dangerous in large quantities.) However, most everyone would agree about the other exhaust emissions shown in Figure 6-1 above. Those other emissions *are* pollutants. As such, they are highly undesirable in the air you breathe. Let's look at each one in some detail.



Since the late 1960s, cars have had devices attached that are designed to decrease carburetor and fuel-tank evaporation and crankcase blowby. Sixty-five percent of the hydrocarbon emissions come out the exhaust, however.

Not all the gasoline put in a fuel tank gets burned in the engine. Some of it evaporates first, and some of it passes through the engine unburned or only partly burned.

Most late-model cars — from 1975 on — have what are called *catalytic converters* built into their exhaust systems (see Figure 6-2 below). A catalyst in one converter helps the left-over hydrocarbons burn up in the exhaust system.

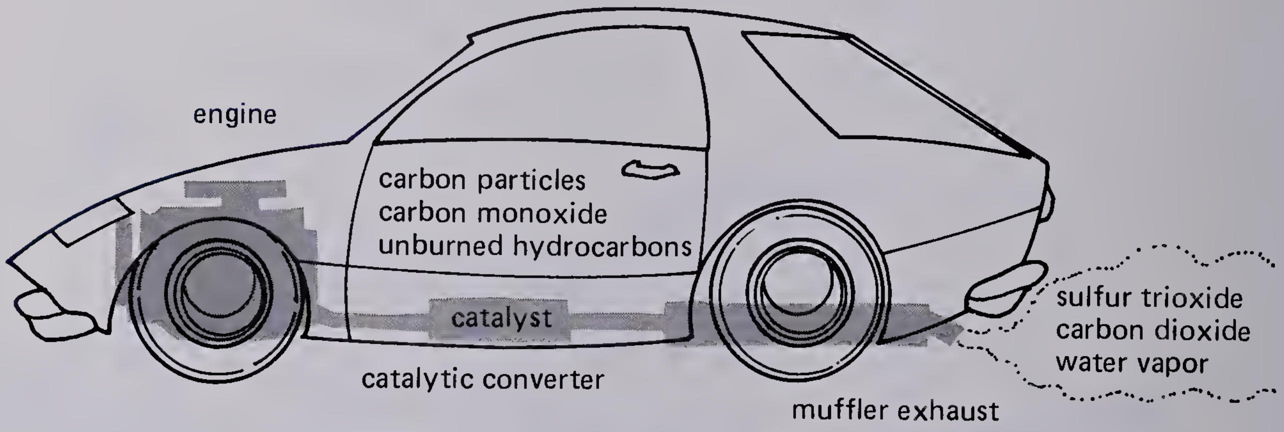


Figure 6-2

In a poorly tuned car, you can sometimes see black, sooty, carbon particles coming out the exhaust pipe. But even a finely tuned engine emits invisible carbon particles. A catalyst can help the burning and eliminate this source of pollution.

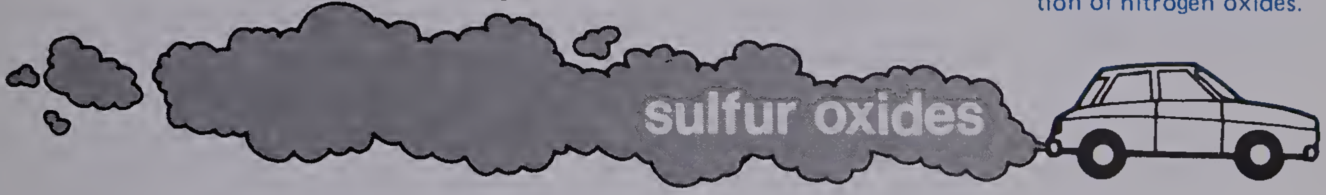
The partial burning of gasoline in an engine also forms carbon monoxide. But, again, a catalyst can help complete the burning, changing poisonous carbon monoxide into carbon dioxide.

- 6-2. What three pollutants do catalytic converters help reduce? What nonpollutants are formed in the process?

6-2. Carbon monoxide, carbon particles, and unburned hydrocarbons; water vapor and carbon dioxide

In the high temperatures of a car engine, some of the nitrogen in the air burns to form nitrogen oxides. A second catalytic converter breaks down these nitrogen oxides.

More complete combustion of gasoline requires higher temperatures, which also favor the formation of nitrogen oxides.

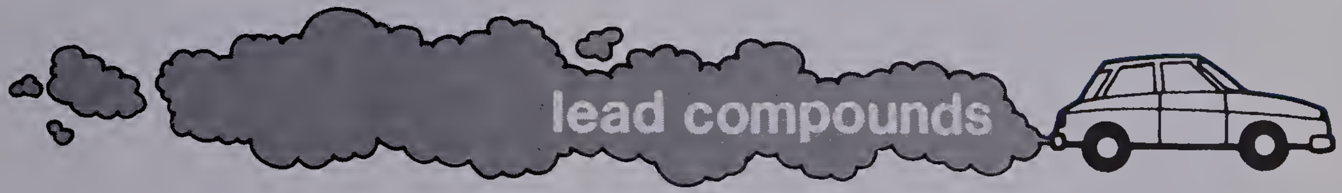


All gasoline contains some sulfur compounds. When they burn in an engine, sulfur dioxide is produced. In the atmosphere, sulfur dioxide is changed into sulfur trioxide. The sulfur trioxide then reacts with water to form sulfuric acid — a very corrosive pollutant. Unfortunately, a catalytic converter will change all the sulfur dioxide passing through it into sulfur trioxide. For a slight increase in cost, however, it is possible to produce gasoline with very little sulfur in it.

Sulfuric acid pollution from the converter is very localized.

● 6-3. What effects do catalytic converters have on nitrogen oxides and sulfur dioxide?

6-3. Catalytic converters break down nitrogen oxides and change sulfur dioxide to sulfur trioxide.



Tetraethyllead is added to many gasolines to improve antiknock quality. But burning these gasolines produces lead compounds as pollutants. The solution is simple — make unleaded gasolines.

If a car has catalytic converters, it must already use unleaded gasoline. Lead compounds would ruin the catalysts in the converters. High-octane unleaded gasolines are available.

● 6-4. What can be done about the problem of sulfur and lead pollutants in automobile engine emissions?

6-4. Produce low-sulfur, unleaded gasolines

☆ **6-5. When a car with catalytic converters burns unleaded gasoline, an undesirable product is emitted by the exhaust. What is this pollutant product?**

6-5. Sulfur trioxide (which reacts with water to form sulfuric acid)

☆ **6-6. When a car without catalytic converters burns gasoline, what pollutants are normally emitted by the exhaust?**

6-6. Carbon particles, carbon monoxide, unburned hydrocarbons, nitrogen oxides, and perhaps (if there is tetraethyllead in the gasoline) lead compounds

ACTIVITY EMPHASIS: Graphs and tables show that world and U.S. consumption of fossil fuels is increasing faster than fuels can be supplied. The U.S. has minable coal in greatest supply, natural gas and crude oil in very short supply.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter.

7-1. Increasing population and increasing energy use per person

The linearization of these graphs, done to aid student understanding, makes the extrapolations very rough. Don't trust them too far.

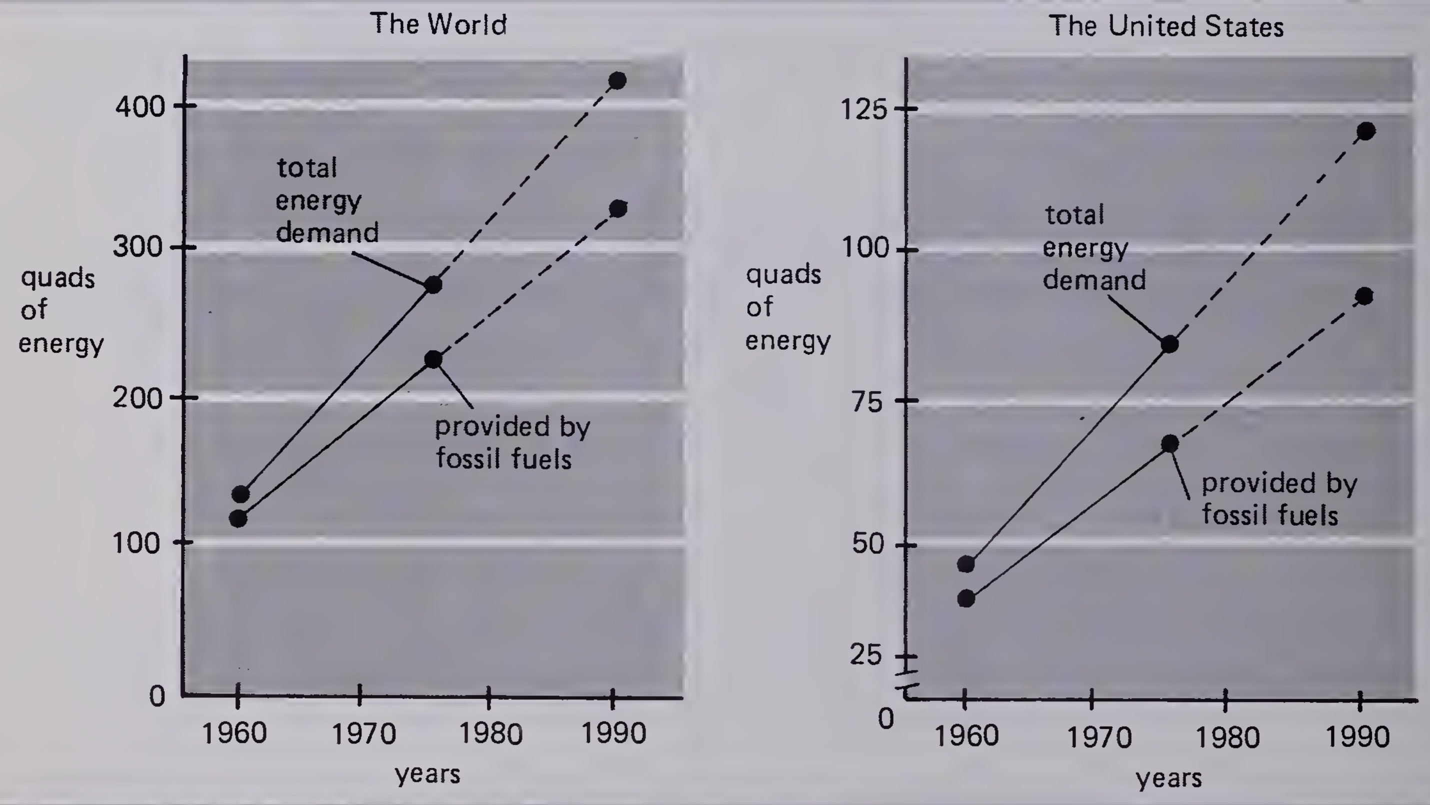
ACTIVITY 7: GONE TODAY

Earth's population is over four billion and getting larger every day. At the same time, the amount of energy used per person is also increasing. Therefore, the fuels that are used to produce energy — mainly fossil fuels — are being used at a faster rate than ever before.

● 7-1. What are two factors contributing to the increasing use of fossil fuels in the world?

Graphs and tables are perhaps the easiest way to present information on production and use. Look at the graphs in Figure 7-1 below. They show how energy demand is increasing in the U.S. and the world. They also show how much of this demand is being met by fossil fuels. The graphs begin with 1960 and are projected to 1990. Then answer Question 7-2 (page 31).

Two graph lines on each grid permit comparison of energy data for the U.S. and the World. Note, however, that the vertical scales are not the same.



What's a *quad*? It's the amount of heat needed to heat 5 billion tonnes of water from 0°C to 100°C. To get a quad, burn 29 billion litres (183 million barrels) of oil, 28 trillion litres of natural gas, or 36 million tonnes of coal.

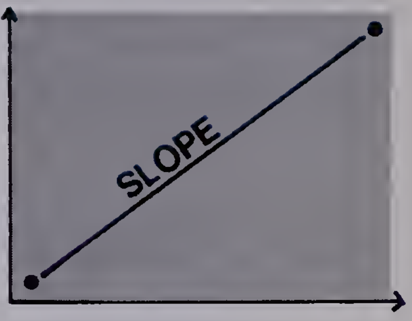
Figure 7-1

● 7-2. What trend appears on the two graphs of energy demand? On the two graphs of fossil fuel use?

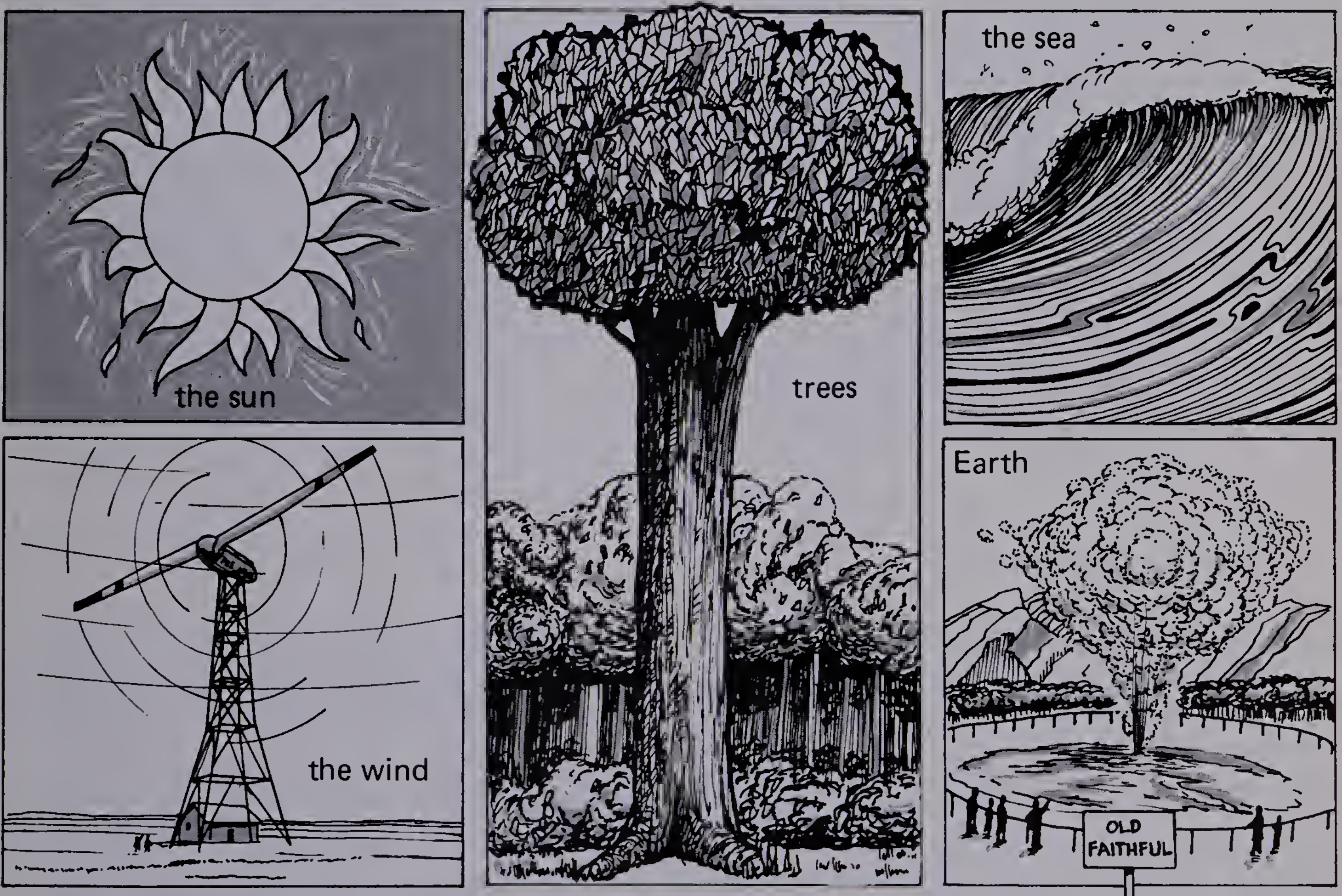
7-2. Total energy demand is increasing in both the U.S. and world; energy provided by fossil fuels is increasing in both the U.S. and world; the gap between the two is widening.

If you had trouble answering Question 7-2 above, review "Trends from Graphs" in "Resource Unit 2: Reading Graphs" now. Then continue.

For both the U.S. and the world, the *slope* of the total energy demand graph is steeper than the *slope* of the fossil fuel graph. Thus the trend is that the increase in the total demand for energy is greater than the increase in the amount of energy provided by fossil fuels. Less and less of the world's energy needs can be met by fossil fuels. The resulting "energy gap" is being bridged by supplies from other sources — wood and nuclear energy, to name two.



ALTERNATE SOURCES OF RENEWABLE ENERGY



● 7-3. Name some more possible energy sources that are not fossil fuels.

7-3. [Answers will vary. Possibilities include wind, hydropower, geothermal energy, sunlight, tides, and nuclear fission.]

● 7-4. Look at Figure 7-1 on page 30 again. Use the graphs to estimate how many quads of energy the U.S. is projected to get by 1990 from sources other than fossil fuels.

7-4. About 30

Are the trends the same for all kinds of fossil fuels? Look at Figure 7-2 below. It compares the use trends of three different fossil fuels from 1960 projected through 1990. Then answer Questions 7-5 through 7-7 following the figure.

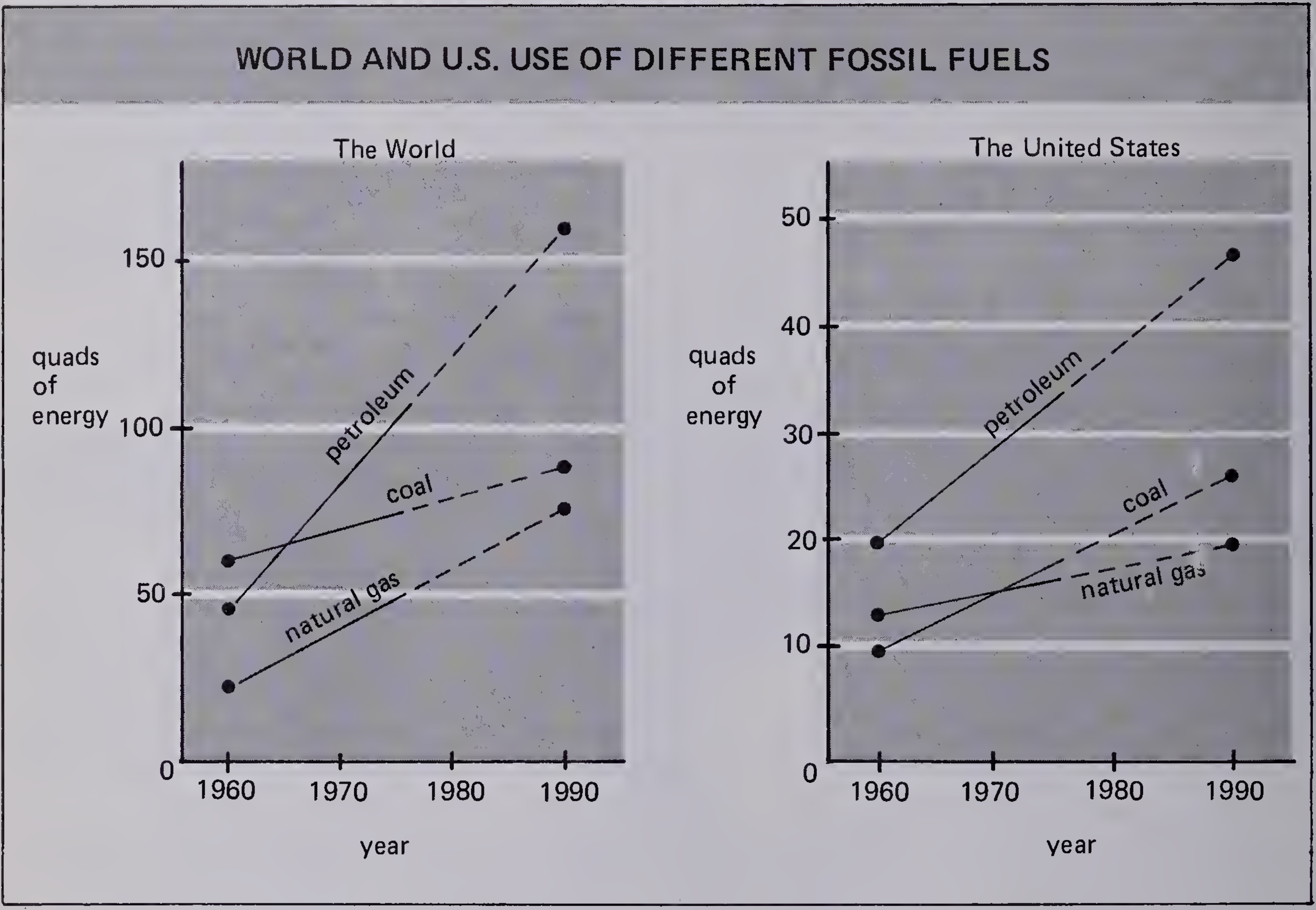


Figure 7-2

7-5. They are all increasing.

☆ **7-5. What trends are there, in the U.S. and around the world, in the use of petroleum? Of coal? Of natural gas?**

7-6. Petroleum; petroleum

☆ **7-6. Which fossil fuel is increasing in use fastest around the world? In the U.S.?**

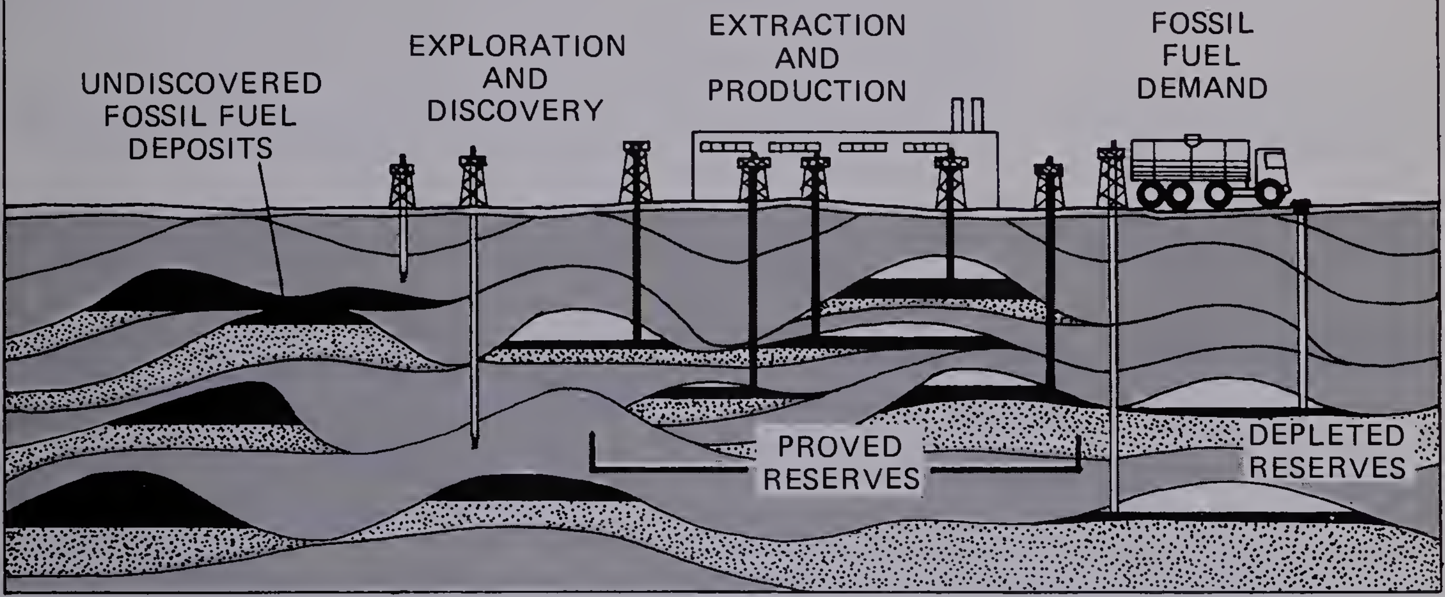
7-7. In the U.S. the use of coal is increasing faster than the use of natural gas. The opposite is true in the world as a whole. [Because the vertical scales are not the same for the two grids, you shouldn't try to compare slopes of the graph lines unless they appear on the same grid.]

☆ **7-7. What trends in the use of fossil fuels are clearly different in the U.S. from what they are around the world?**

As Figure 7-2 above clearly shows, the use of fossil fuels is increasing. That's true both in the U.S. and around the world. But increasing use isn't the whole story. There's the matter of supply.

You learned in Activity 2 that the world's fossil fuels are limited in total amount. When they get *depleted* (used up), there won't be any more — not for many thousands of years, anyhow. Of course, not all the world's fossil fuels have been discovered yet. But the likely places to find them are getting scarce.

The known deposits of fossil fuels are called PROVED RESERVES. New discoveries can add to proved reserves, delaying depletion. And data about proved reserves, together with data about production, give early warning of approaching depletion.


UNDISCOVERED FOSSIL FUEL DEPOSITS
EXPLORATION AND DISCOVERY
EXTRACTION AND PRODUCTION
FOSSIL FUEL DEMAND
PROVED RESERVES
DEPLETED RESERVES

● 7-8. What are *proved reserves*?

7-8. Known supplies of coal, natural gas, and petroleum

Look at Figure 7-3 below. It shows the situation with U.S. domestic crude oil supplies. (Tables can look scarier than graphs. That's because trends are harder to spot. The trick is to look at just a part of the table at a time.)

AVAILABLE SUPPLIES OF U.S. CRUDE OIL (in billions of barrels of 159 litres each)					
Year	Production	New Oil Found	Amount of Depletion	Proved Reserves	NUMBER OF YEARS OF SUPPLY LEFT
1960	2.5	2.4	0.1	32	12.8
1965	2.7	3.0	−0.3	31	11.7
1970	3.3	3.0	3.0	39	11.7
1975	2.9	1.3	1.6	33	11.3

Figure 7-3

● 7-9. From Figure 7-3 above, what was the trend in U.S. crude oil production between 1960 and 1970? Between 1970 and 1975?

7-9. Production increased; production decreased.

7-10. Decreased slightly 1960-65; increased 1965-1970; decreased 1970-75

☆ **7-10. Use Figure 7-3 (page 33) to describe the trends in proved U.S. reserves (known supplies) of crude oil for each five-year period between 1960 and 1975.**

In 1975, the U.S. had a slightly larger crude oil proved reserve available (33 billion barrels) than in 1960 (32 billion barrels). This might seem to be an improvement. But it's not. In 1960, the 32 billion barrel reserve was a 12.8 year supply, based on that year's production. In 1975, the 33 billion barrel reserve was only an 11.3 year supply. This trend of decline in the U.S. supply of crude oil continues.

7-11. New supplies (proved reserves) were found.

● 7-11. If the U.S. had a 12.8 year supply of crude oil in 1960, why wasn't the supply exhausted by 1975?

What about the trend in the supply of natural gas? Look at Figure 7-4 below.

AVAILABLE SUPPLIES OF U.S. NATURAL GAS
(in trillions of cubic feet of 28 litres each)

Year	Production	New Gas Found	Amount of Depletion	Proved Reserves	NUMBER OF YEARS OF SUPPLY LEFT
1960	13	14	–1	262	20
1965	16	21	–5	286	18
1970	22	27	–5	290	13
1974	21	9	12	237	11

Figure 7-4

7-12. Decreasing (or declining)

☆ **7-12. From Figure 7-4 above, what is the continuing trend in U.S. natural gas supplies, expressed in years of supply?**

In the U.S., supplies of both crude oil and natural gas are dwindling. But coal reserves are holding up well. Current estimates peg the U.S. coal supply at about 400 years (at the current production rate).

7-13. Coal; natural gas

☆ **7-13. Of the three main fossil fuels — coal, crude oil, and natural gas — which is in greatest supply in the U.S.? In least supply?**

The relationship between demand, production, and imports is not simply additive. It is complicated by exports, storage, and inventory.

The data so far are still incomplete. They describe domestic supply and production. But what about domestic demand? Does the U.S. produce all the fossil fuels it demands (and uses)? For the answer where crude oil is concerned, look at Figure 7-5 on page 35.

BILLIONS OF BARRELS OF CRUDE OIL, U.S.				
Year	Demand	Produced	Imported	Percent of Demand Imported
1960	3.6	2.5	0.7	19
1965	4.2	2.7	0.9	21
1970	5.4	3.3	1.3	23
1975	5.9	2.9	2.2	37

Figure 7-5

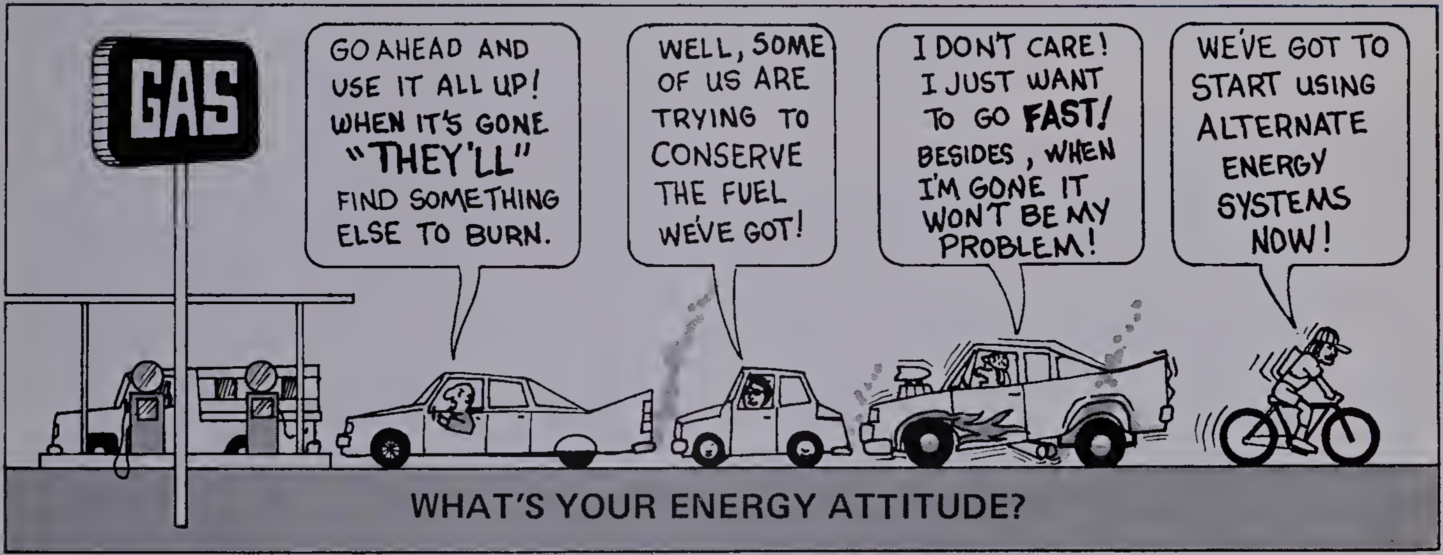
☆ **7-14. U.S. demand for crude oil has been steadily increasing. What trends do you see in the amount of crude oil imported from other countries and its percentage of U.S. demand?**

7-14. Imports have been increasing in amount and percentage of demand.

☆ **7-15. Why must the U.S. import crude oil?**

7-15. Domestic production doesn't meet domestic demand.

If current trends continue, supplies of crude oil and natural gas will run out. This might well happen in your lifetime. Before that happens, what can and should be done?


GAS
GO AHEAD AND USE IT ALL UP! WHEN IT'S GONE "THEY'LL" FIND SOMETHING ELSE TO BURN.
WELL, SOME OF US ARE TRYING TO CONSERVE THE FUEL WE'VE GOT!
I DON'T CARE! I JUST WANT TO GO FAST! BESIDES, WHEN I'M GONE IT WON'T BE MY PROBLEM!
WE'VE GOT TO START USING ALTERNATE ENERGY SYSTEMS NOW!

WHAT'S YOUR ENERGY ATTITUDE?

In certain uses, crude oil and natural gas are irreplaceable. They are used as lubricants or raw materials in many industries, in defense, in transportation, and in agriculture. But other energy sources are available for heating and electricity generation. Coal, nuclear power, and several others may be developed and used.

In the meantime, more efficient use can be made of fossil fuels. Smaller cars with smaller engines, lowered highway speeds, and better home insulation are just three examples.

● 7-16. What two things can be done to preserve dwindling supplies of natural gas and crude oil?

7-16. Develop and use other energy sources; meanwhile use current fuels more efficiently.

ACTIVITY 8: THE SIDE EFFECTS

ACTIVITY EMPHASIS: Obtaining and transporting fossil fuels can cause environmental problems — damage to land, water, and living things.

MATERIALS PER STUDENT LAB GROUP: None

COAL

People use the energy from fossil fuels to make their lives easier and more comfortable. But whenever fossil fuels are produced or used, there will be some effects on the environment — the air, water, and land. Whenever people use energy, they must decide if that use is worth the possible side effects. To make the side effects as small as possible, it's often necessary to use more energy.

Energy producers are looking more and more to coal as a main energy source. But mining it brings environmental problems. Coal is mined either on the surface or underground. Figure 8-1 below shows how surface mining is often done.

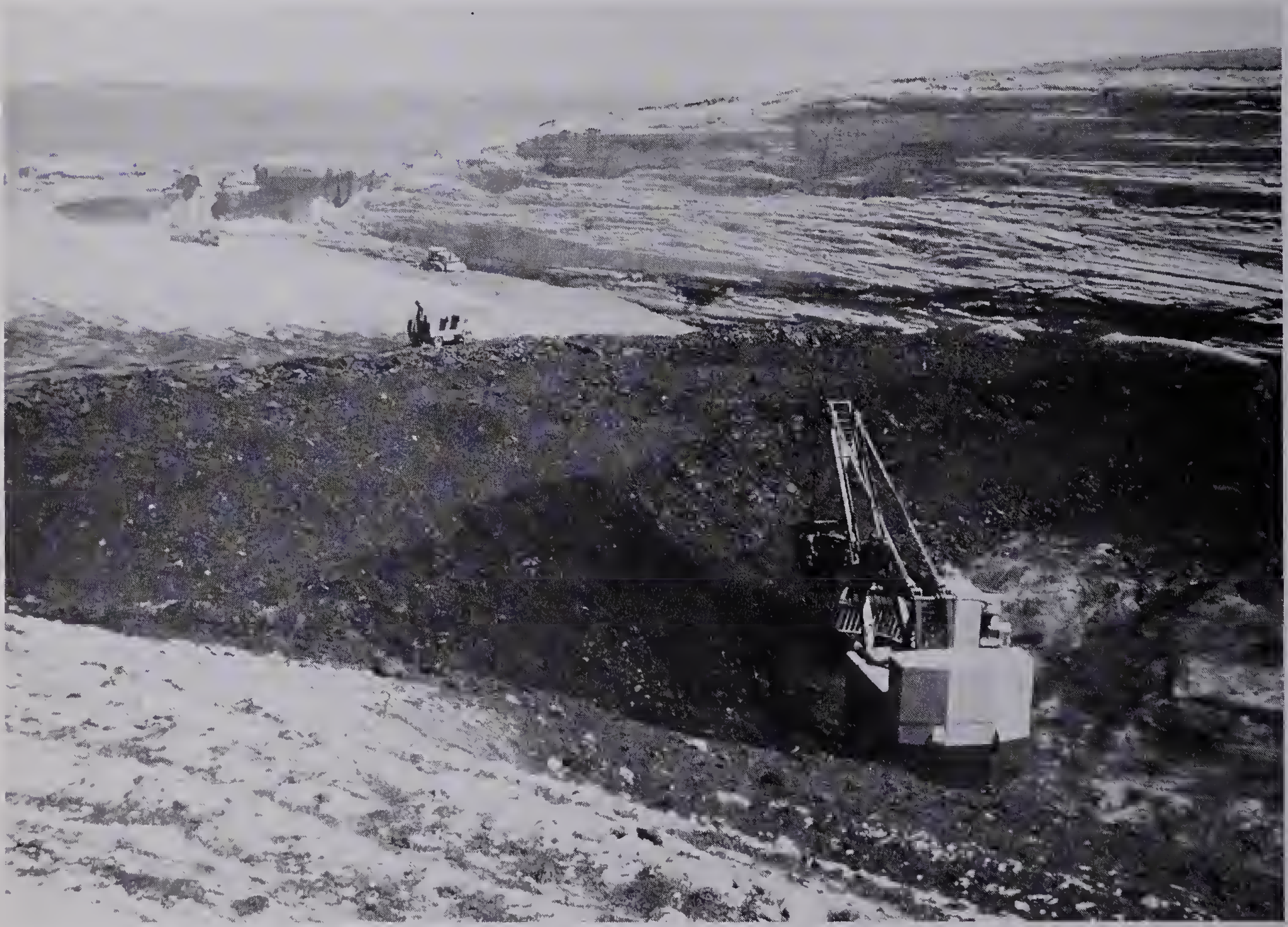


Figure 8-1

In surface mining, the land is first cleared. Then layers of rock and earth are removed to expose the coal. The coal is then loosened and hauled away.

Figure 8-2 below shows a land area soon after it has been surface mined.

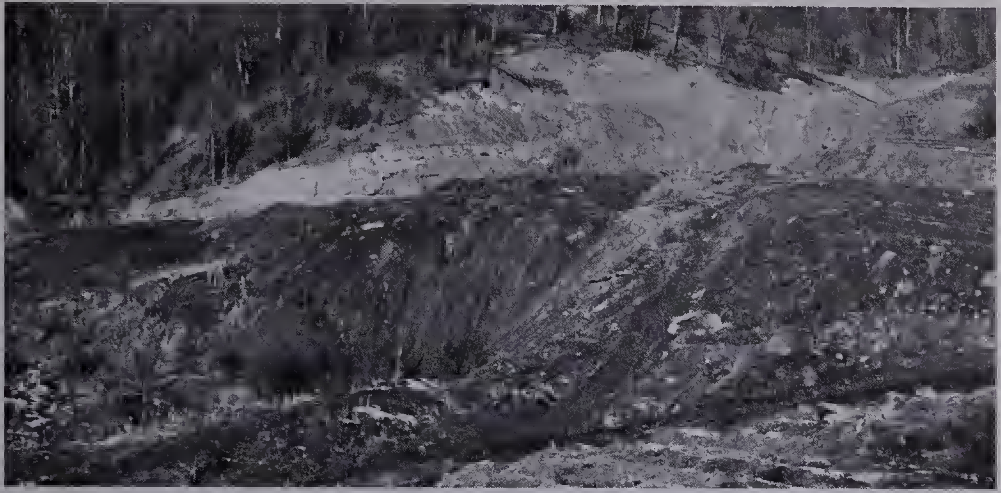


Figure 8-2

What remains is barren, rocky ridges and furrows of broken land. Without any covering vegetation, rain and runoff quickly carve out deep gulleys of erosion. And sometimes poisonous substances, exposed by the mining, get washed into nearby lakes and streams. So people in the area can find their land scarred and their waters polluted.

☆ **8-1. When coal is surface mined, what are the possible side effects on the land? On nearby bodies of water?**

8-1. Scarring and erosion; pollution by poisonous runoffs.

Reducing the side effects of surface mining is a big job. But it can be done. In Figure 8-3 below the same area is shown as in Figure 8-2 above. But this second photo was taken after the land had been *reclaimed*. Topsoil had been replaced and vegetation planted, making the land useful once again.

In the United States, about a million and a half acres of land have been surface mined. By 1971, about a third of them had been reclaimed.

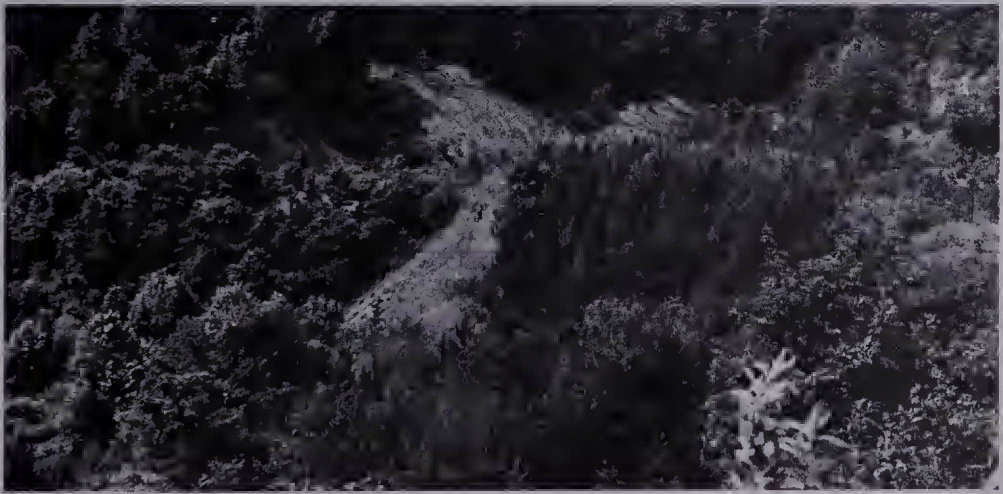
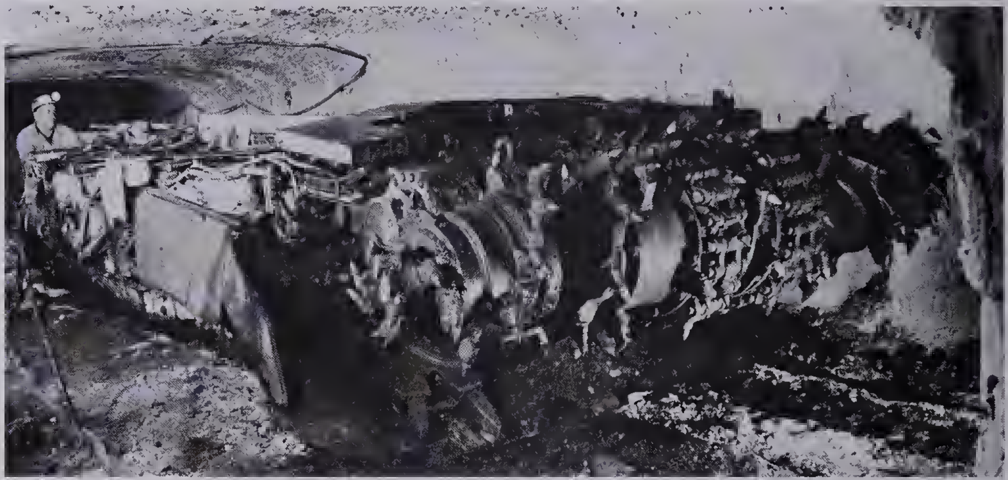


Figure 8-3

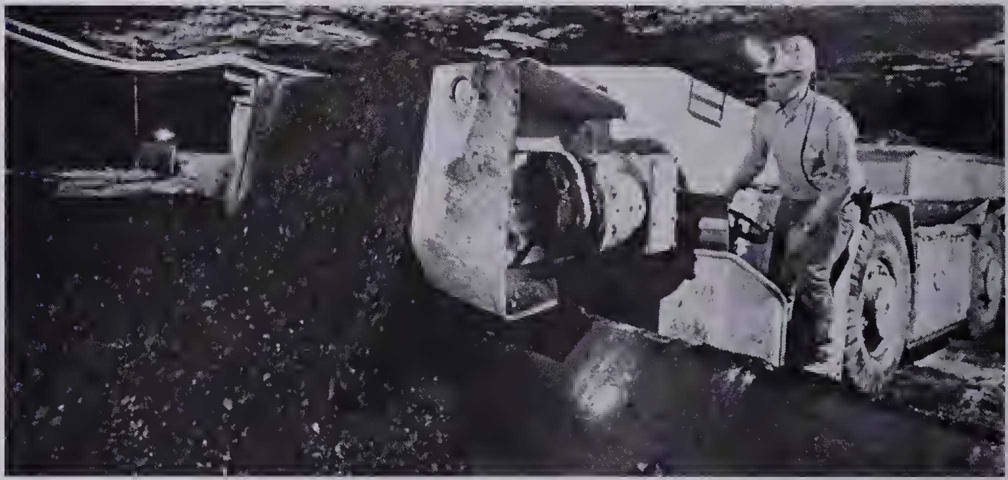
Mining the coal underground costs more than mining it on the surface. It's also more dangerous to miners. And while the land surface is not scarred, land sinkings and cave-ins do occur. This creates problems of land use, especially in urban areas. Lakes and streams can also be polluted by mining wastes carried by rainfall and groundwater. An underground mine is shown in Figure 8-4 below.

The U.S. Department of the Interior estimates that eight million acres have been undermined by coal mining and that about two million of those acres have subsided.

Acidic mine drainage has polluted more than ten thousand miles of rivers and streams in coal mining areas. The U.S. Department of the Interior estimates acid-drainage control costs in the United States at six and a half billion dollars.



A continuous mining machine rips coal from the walls of the mine.



Shuttle cars transport the coal to a conveyor belt.

Figure 8-4

● 8-2. Why would cave-ins be particularly dangerous in urban areas?

☆ **8-3. What environmental side effects does underground coal mining have on the land and water?**

A number of mine safety laws and practices are aimed at controlling cave-ins and mine drainage. They help reduce these side effects.

The washing of coal to remove impurities makes coal mining the third largest producer of industrial wastes.

8-2. People can be injured or killed, and buildings can be damaged.

8-3. Cave-ins and water pollution

CRUDE OIL

The various methods of drilling, pumping, and transporting crude oil also have possible side effects. Land-based drilling and pumping are relatively trouble-free (see Figure 8-5 below).

Figure 8-5

Drilling doesn't affect a very large land area (in fact, some wells are located right next to public buildings). But drilling under water can create problems (Figure 8-6 below).

Figure 8-6

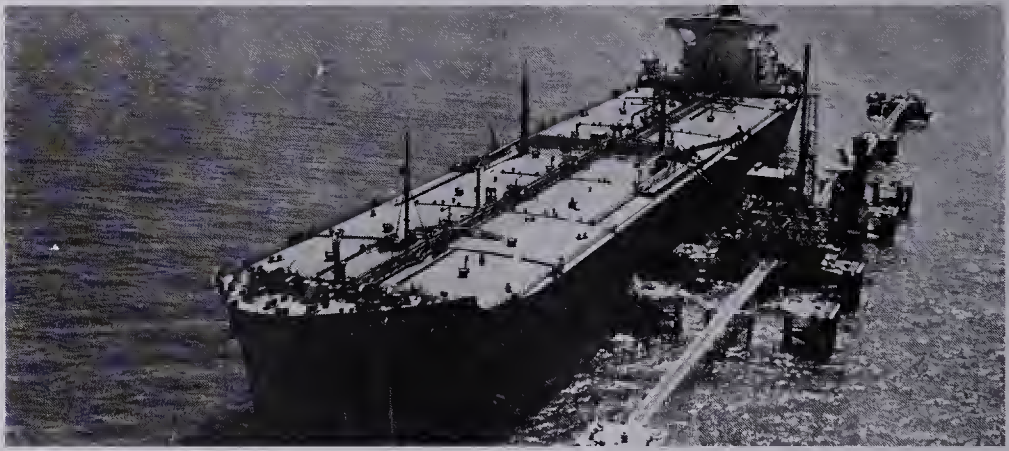
Although quite rare, blowouts at offshore oil rigs can occur. The Santa Barbara (California) blowout of 1969 leaked more than a million litres of crude oil into the Pacific Ocean and polluted miles of coastline.

Only four significant blowouts in U.S. waters have resulted from offshore drilling so far, out of thousands of producing wells.

In 1967, a leaky pipeline spilled about twenty-seven million litres of oil into the Gulf of Mexico. In 1968, the tanker *Torrey Canyon* spilled more than a hundred million litres of oil off England, and the cleanup cost twenty-two million dollars. In 1978, the supertanker, *Amoco Cadiz* spilled almost ninety million litres of oil off the French coast. The cost has not yet been reckoned.

A much graver problem, however, is raised by the transport of crude oil over land or water. Breaks or leaks in pipelines, accidents to oil tankers, and even routine ship operations can result in serious oil spillage. In recent years there has been increasing internation cooperation in estimating the extent of oil spillage at sea. And many countries are working to bring it under control.

TANKER AT SEA



TANKERS UNLOADING AT OFFSHORE PIPELINE

8-4. Tanker accidents, ship operations, pipeline leaks, and well blowouts

☆ 8-4. What are sources of crude oil spills in the ocean?

Oil spilled on water has much greater environmental side effects than oil spilled on land. On land, the spill can be controlled. On water, the oil spreads into huge slicks, fouling beaches and killing birds and shellfish. Long-term effects caused by substances in the oil are also possible. Crude oil spills are better prevented than cleaned up.

Of special interest is the crude oil being pumped from Alaska's North Shore. The Alaskan tundra environment is very fragile. An oil spill on the land or ice there has more serious effects than a similar spill somewhere else.

A large spill on the ice could cause significant melting because of the greater absorption of the sun's energy.

If a lot of pipeline oil were spilled, it might take years for the environment to recover. The companies that drill for the crude oil and build and maintain the pipeline have spent much money to reduce these dangers to the environment. But the dangers do exist.

☆ **8-5. What are some of the environmental problems related to drilling for and transporting crude oil?**

8-5. Oil spilled in water can foul beaches, kill birds and shellfish, and add poisonous chemicals. Oil spilled in the Arctic can damage the tundra.

TRANS ALASKA PIPELINE

OIL SHALE

The Green River formation in Colorado, Utah, and Wyoming contains about a hundred trillion litres of oil trapped in high-grade deposits. A tonne of oil shale has about a seventh of the energy content of a tonne of coal, but the oil content varies greatly.

Because of the processing, the volume of waste to be disposed of is greater than the volume of mined rock. It won't fit back into the hole it came from. Air pollution control is also a problem.

A great deal of attention these days is being paid to the possibilities of getting oil from rock called *oil shale*. In one method, the shale must be mined. Then the oil is driven out by heating the crushed rock. There are problems with the process — reclaiming the disturbed land after mining and disposing of the waste rock powder.

Another possible method is to break up and heat the oil shale while it is still in the ground. This method is not yet commercial and may also have unwanted side effects.

☆ **8-6. What are two environmental problems with obtaining oil from oil shale?**

8-6. Reclaiming the land and disposing of the waste [A third problem is air-pollution control.]

ACTIVITY 9: FROM ONE FORM TO ANOTHER

ACTIVITY EMPHASIS: When a fossil fuel is burned in an electrical power plant, sixty percent of the stored energy released as heat is wasted. But the amount wasted plus the amount used to produce electricity equals the amount released by the fuel when it burned — energy is conserved.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

Every minute of the day or night some form of fossil fuel is being burned to release energy. The energy does such things as heat homes, cook food, run cars and other machines, and produce electricity.

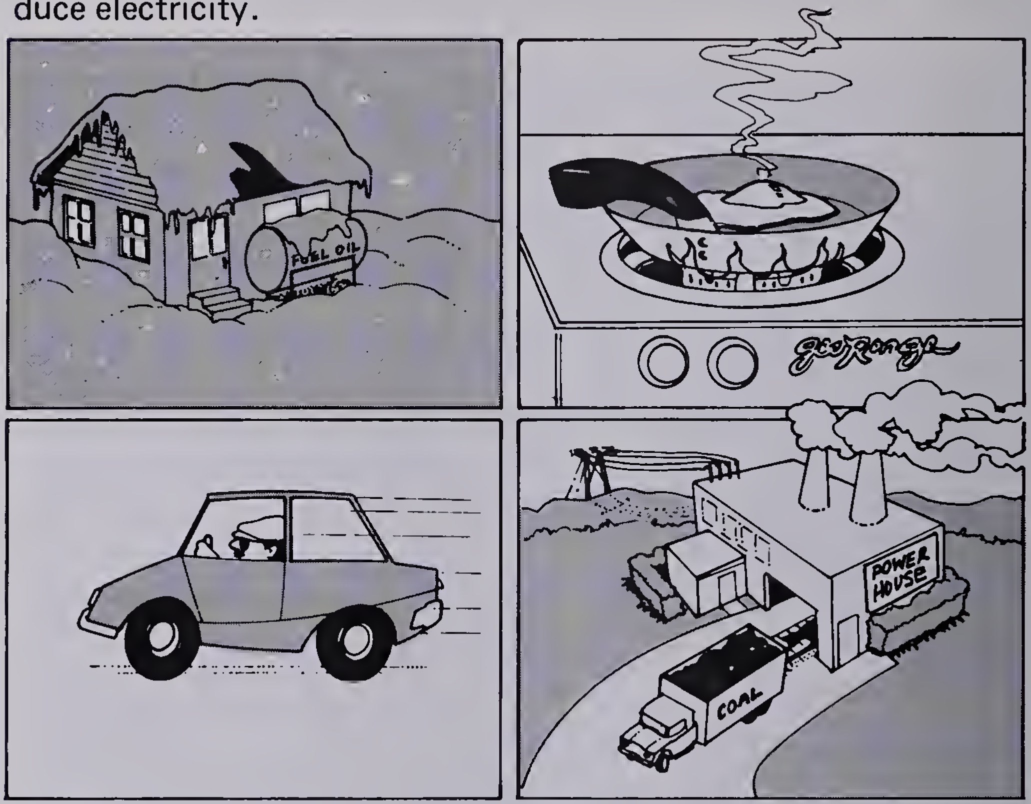


Figure 9-1

Look at the examples in Figure 9-1 above. In each case, the stored chemical energy in a fossil fuel has been released. It has been changed into another form of energy — mechanical energy or heat energy or electrical energy.

9-1. A2, B1, C1, D3

● 9-1. Fossil fuels are used to provide other forms of energy in each of the examples shown in Figure 9-1 above. Match each example with one of the energy changes shown below.

Example	Energy Change from Chemical Energy
A. Car	1. to heat energy
B. Stove	2. to mechanical energy
C. Furnace	3. to electrical energy
D. Power plant	

When fossil fuels burn, they combine chemically with oxygen to form other substances. The chemical energy stored in the fuel is released — mostly as heat energy. This heat energy can then either be used directly or changed into still other forms of energy.

In a car engine, for example, gasoline is burned. The chemical energy is changed to heat energy, some of which is changed to mechanical energy that moves the car. Or take the case of the light that's on in your room right now. The electricity for it may come from a coal-burning generating plant. If so, the light you are reading by is still another form of the energy that came from the coal! Look at Figure 9-2 below.

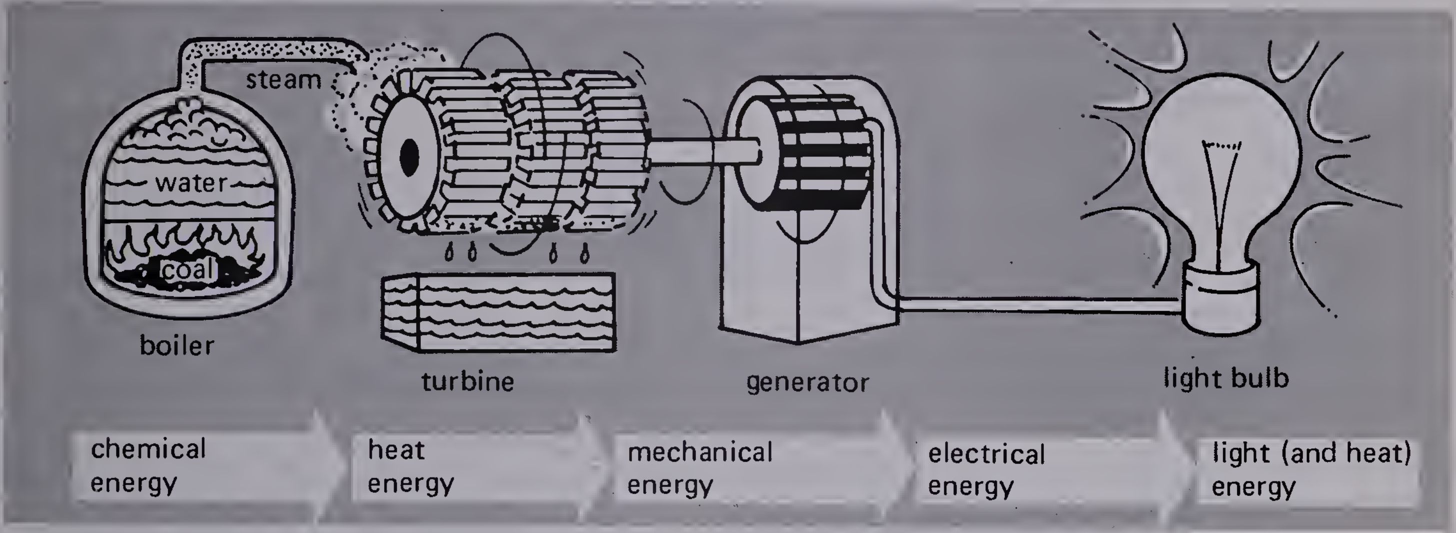


Figure 9-2

☆ **9-2. List in order the five forms of energy involved in producing electric lighting from a fossil fuel.**

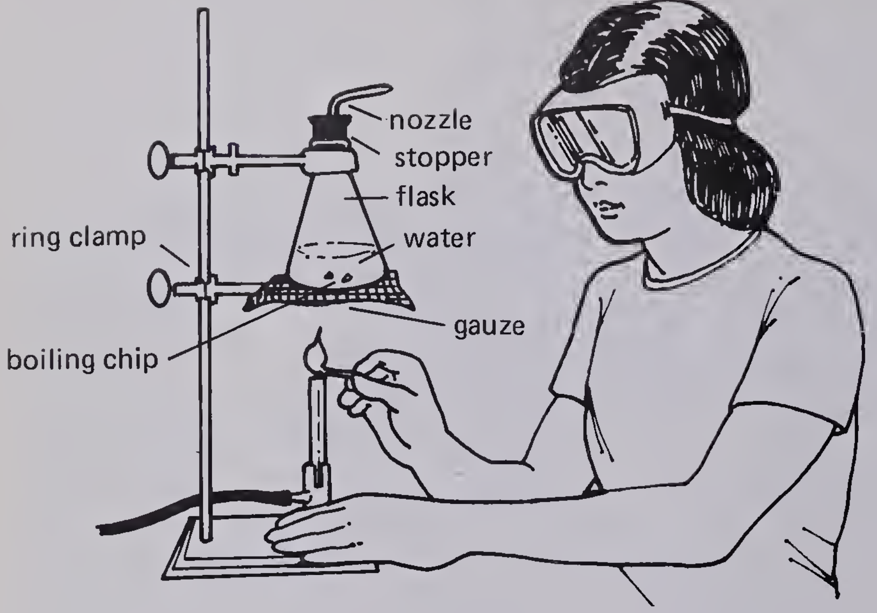
9-2. Chemical, heat, mechanical, electrical, and light (also heat as by-product)

Of course, the electricity from the generator could be used in many other ways too. To get a better idea of the flow of energy in the electricity-generating process, you can make a model. You'll need a partner, thirty minutes, and the following materials.

safety goggles
Bunsen burner
turbine-generator apparatus
250-ml Erlenmeyer flask
1-hole rubber stopper with glass nozzle
milliammeter
3 test leads with alligator clips
2 ring stands
knife switch
ring and wire gauze
2 utility clamps
boiling chip

If you need help with the burner, read "Resource Unit 17: Using a Burner." Then begin Step A.

CAUTION Remember to wear your safety goggles.

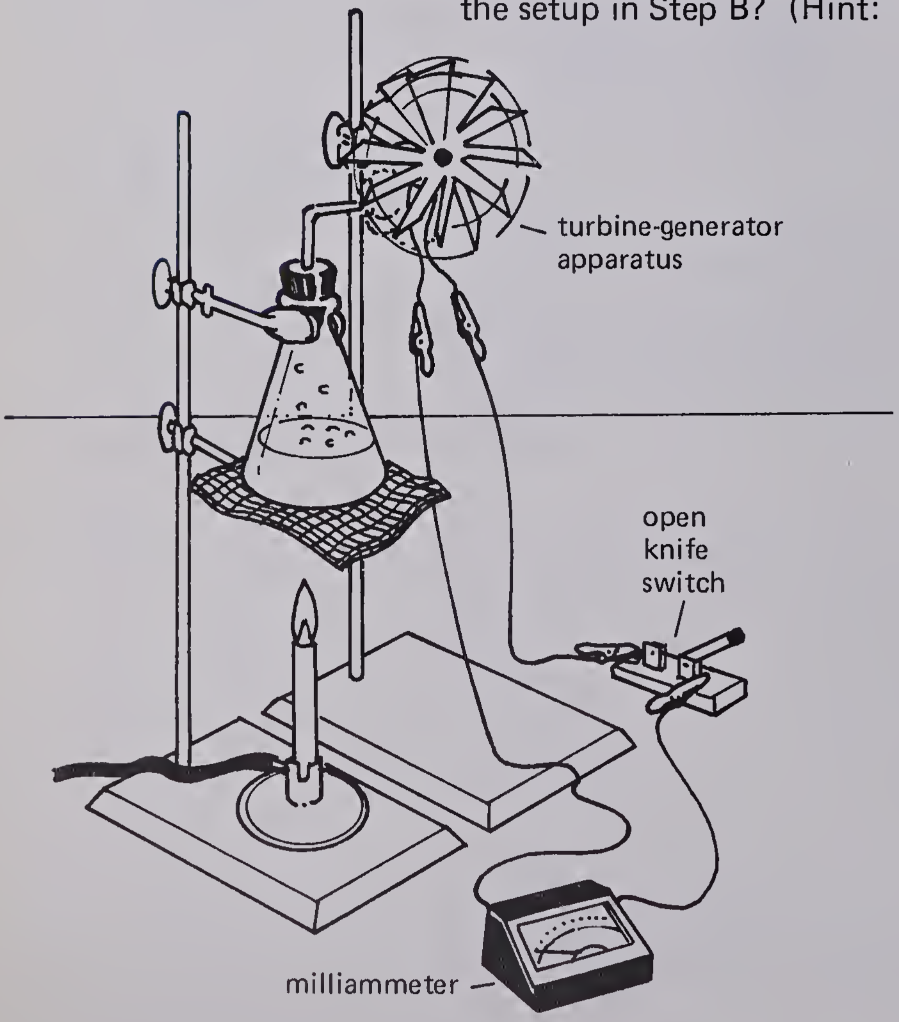


9-3. The boiler

A. Half fill the flask with water. Add a boiling chip. Carefully, but securely, insert the rubber stopper with the glass nozzle into the flask.

B. Set up one ring stand with the ring and gauze. Put the Bunsen burner under the ring. Clamp the flask setup into position. Light the burner.

- 9-3. What part of the electrical power plant is represented by the setup in Step B? (Hint: Check Figure 9-2 on page 43.)

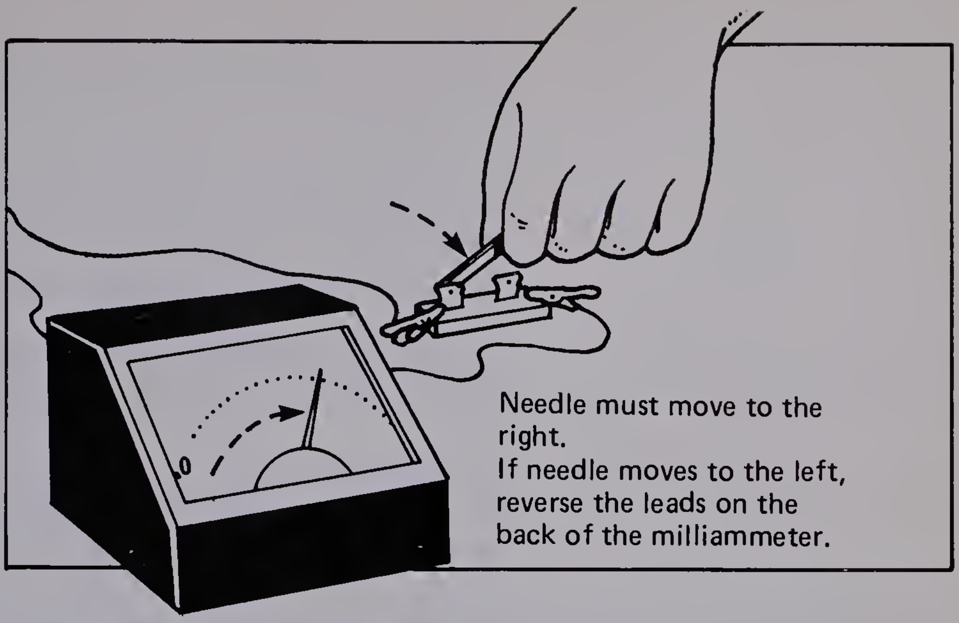


C. Clamp the turbine-generator apparatus onto the other ring stand. Using a test lead, hook up one generator wire to one post on the milliammeter. Hook up the other generator wire to one post of the switch. Hook up the other post of the switch to the other post of the milliammeter. Leave the switch open. Be sure that the alligator clips don't touch each other.

D. Adjust the burner so the water in the "boiler" boils vigorously. Then move the turbine-generator apparatus very near the end of the nozzle. Adjust its position so that steam blows directly on the blades of the turbine. If the blades don't move, give them a little start.

E. Watch the milliammeter while one person closes the switch. If the needle moves to the left of zero, quickly open the switch and reverse the two leads on the posts of the milliammeter. Then close the switch again.

F. Watch as the needle moves to the right as far as it is going to. Then adjust the two setups to get the highest possible reading on the milliammeter.



Needle must move to the right.
If needle moves to the left, reverse the leads on the back of the milliammeter.

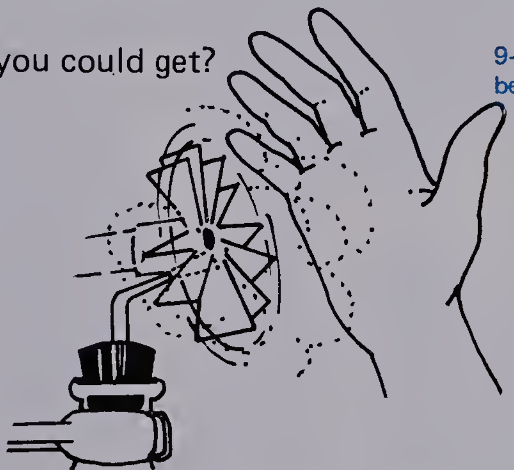
The milliammeter measures the amount of electric current flowing in the wires of your model power plant.

- 9-4. What was the highest reading you could get?

9-4. [Answers will vary—probably between 20 and 30 milliamperes.]

G. Use your hand to feel carefully near the boiler and the turbine generator.

H. Shut off the burner when you're finished.



- 9-5. What happens to the heat produced by the burner? Is it all turned into electricity by the turbine generator? Explain.

9-5. No. Heat can be felt above the boiler and behind the turbine.

You've heard people say that it's important to "conserve energy." What they are talking about is preserving energy resources and using energy more carefully. That's one meaning of the word *conservation*. But there's another, different meaning that's used a lot in science.

Your model has shown you how electricity can be produced from fossil fuels. In so doing, it has also illustrated the *law of conservation of energy*. This doesn't refer to saving energy. It refers to an important scientific idea: that (in nonnuclear energy changes) new energy is not being made nor old energy destroyed. When energy is changed from one form to another, the total amount of energy is constant. That is, the amount before the change is the same as the amount after.

In nuclear energy changes, matter is converted to energy.

But this principle doesn't mean that energy conversion processes are totally efficient. They're not. In electric power plants that burn fossil fuels, only about forty percent of the heat energy produced by burning the fuel becomes electrical energy. The rest of the heat energy is wasted — as heat given up to the surroundings. You got some idea of this waste of heat when you felt various places around your model power plant.

9-6. About sixty percent

● 9-6. About what percentage of the heat energy released by burning ends up being wasted in a power plant?

Figure 9-3 below illustrates the efficiency of a good power plant in changing stored chemical energy into electrical energy. The arrows show how much energy is changed at each step and how much is wasted as heat given up to the surroundings.

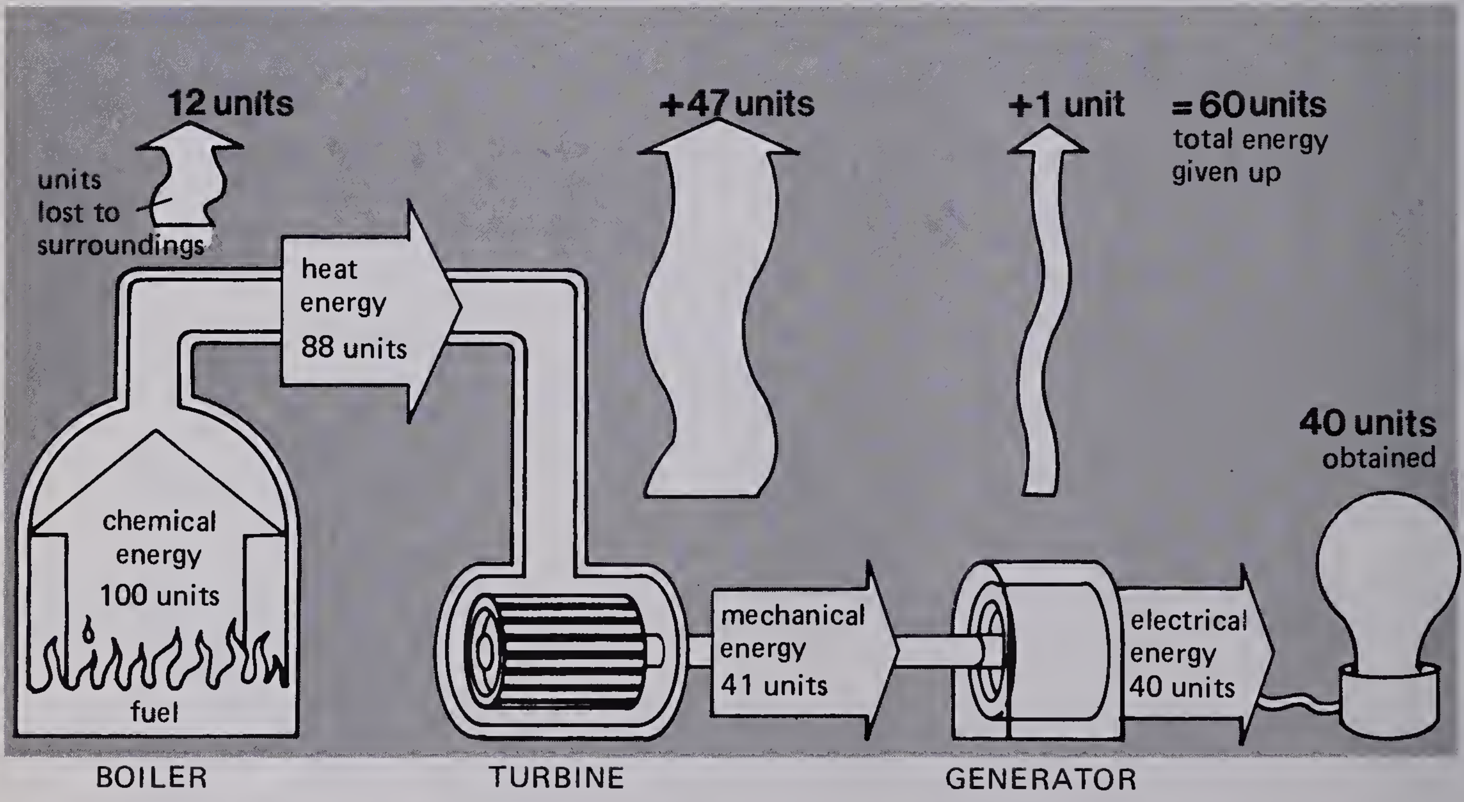

12 units
units lost to surroundings
+47 units
+1 unit
= 60 units total energy given up
heat energy 88 units
chemical energy 100 units
fuel
mechanical energy 41 units
electrical energy 40 units
40 units obtained
BOILER
TURBINE
GENERATOR

Figure 9-3

9-7. 40 units; 60 units

● 9-7. Suppose the fuel being burned in the boiler gives up 100 units of chemical energy. How many units of electrical energy will be obtained? How many units of energy will be given up to the surroundings as wasted heat?

9-8. Energy is conserved since input (100 units) = output (60 units + 40 units).

● 9-8. Figure 9-3 above diagrams a "power plant." How does its operation illustrate the conservation of energy? (Hint: Are energy totals the same before and after?)

A forty-percent transfer of heat energy to electrical energy is considered good. But you can see that heating with electrical devices is not too efficient. Direct burning for heat is much more efficient. Of course, people use electrical energy for many things besides heating. And electrical heating is often very convenient.

Scientists and engineers are trying to raise the efficiency of using fossil fuels to produce other forms of energy. Higher efficiency means lower cost to industry for manufacturing goods. It also means lower prices to consumers and less air and water pollution.

But no matter what is done, there will always be some waste heat. And the principle of the conservation of energy will always apply.

This may be the first time you've run into the idea of conservation of energy. Don't worry if you're still a little unsure about it. You'll see it again in other minicourses. If you've seen it before and want a review, you might read "Resource Unit 18: Matter and Energy," now.

☆ **9-9. State the principle of conservation of energy.**

9-9. In energy change from one form to another, the total amount of energy is the same before and after the change.

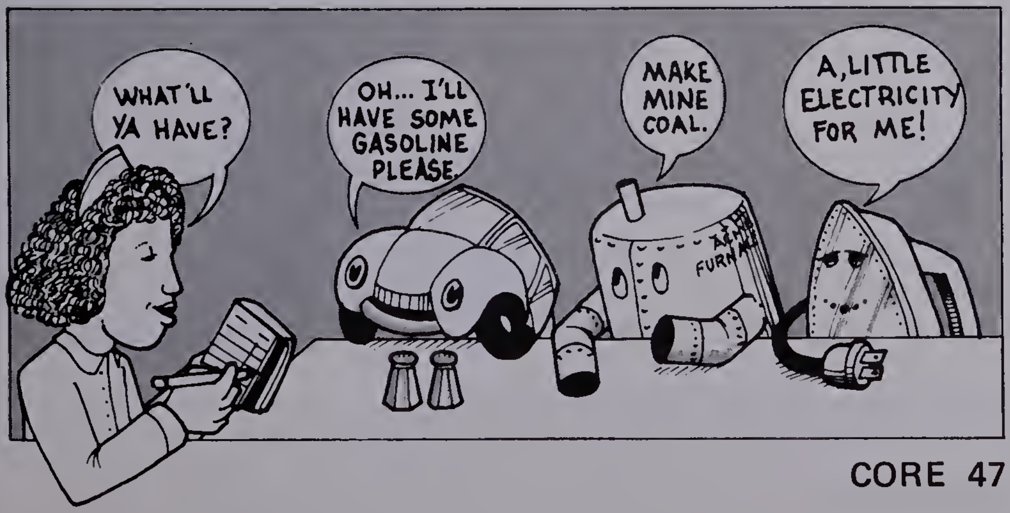
ACTIVITY 10: WHICH FUEL TO USE?

ACTIVITY EMPHASIS: Since the United States has adequate coal supplies, coal can replace oil and natural gas in producing energy. Environmental, safety, and efficiency factors must be considered in the decision about which fuels to use.

MATERIALS PER STUDENT LAB GROUP: None

You probably have a choice about what to eat at lunchtime. Maybe you eat a sandwich brought from home. Or you may eat "junk food" you buy at a nearby store. Or you may eat the hot lunch from the school cafeteria. In any case, you know you need to eat something.

Machines can't choose for themselves the way you can, but they need "food" too — they need energy. And just as you have several possible sources of your food, so machines can be powered by energy from several different sources.

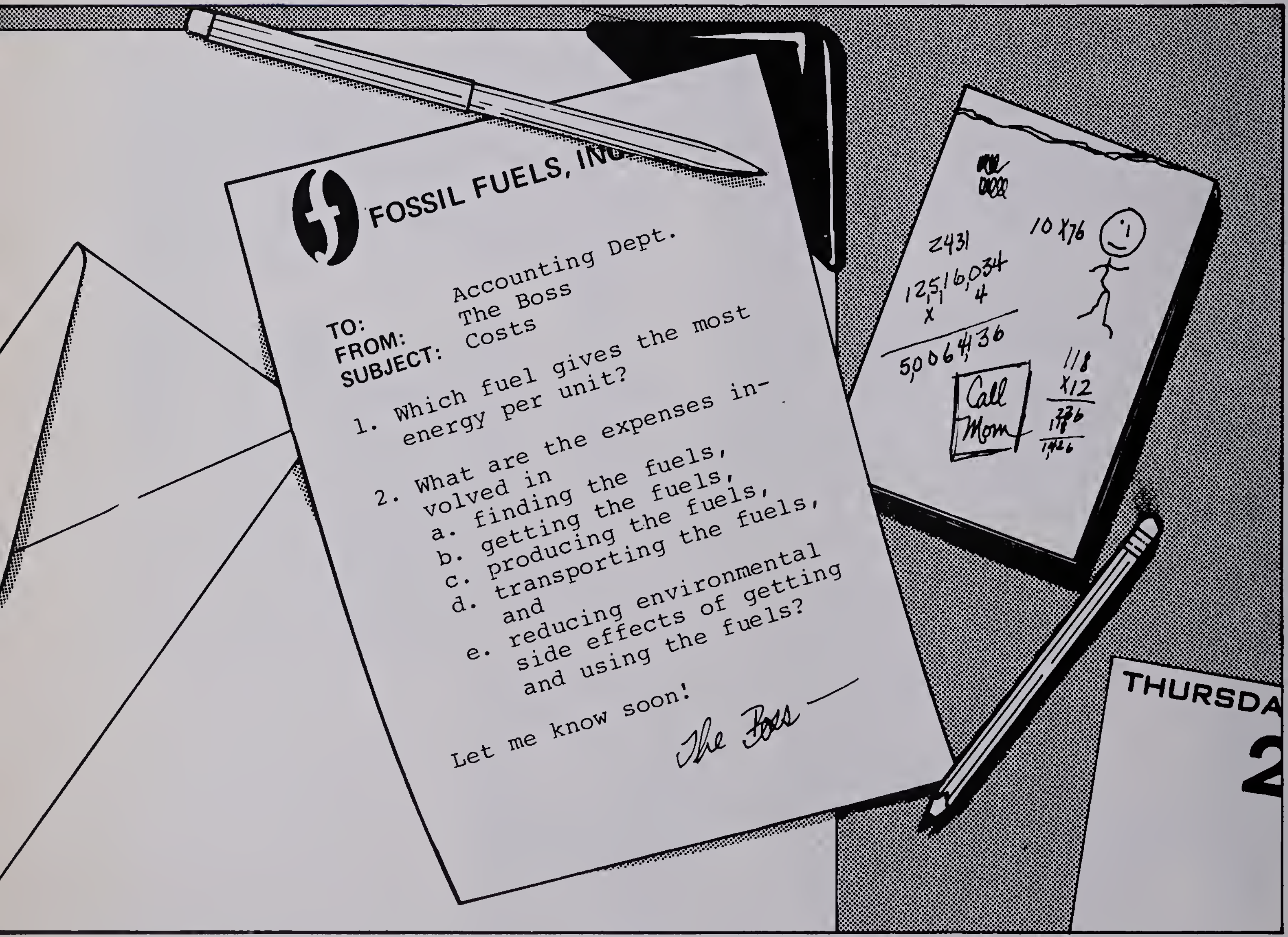

WHAT'LL YA HAVE?
OH... I'LL HAVE SOME GASOLINE PLEASE.
MAKE MINE COAL.
ACM
FURN
A, LITTLE ELECTRICITY FOR ME!

10-1. Fossil fuels — petroleum, natural gas, and coal

- 10-1. What energy source powers most machines today?

But the use of fossil fuels as main energy sources has created problems. As these problems have grown, people have become aware of them and started facing them. One basic issue is the question of choice among the different fossil fuels. Which one should be used for which purpose? Answering this requires consideration of three distinct sets of problems. These are problems of *supply*, problems of *environmental effects*, and problems of *cost*. Look at Figure 10-1 (below and page 49).

Any one of these problems is hard to deal with. When you consider all of them at once, it's really hard to find reasonable solutions.



FOSSIL FUELS, INC.

TO: Accounting Dept.
FROM: The Boss
SUBJECT: Costs

1. Which fuel gives the most energy per unit?

2. What are the expenses involved in
   a. finding the fuels,
   b. getting the fuels,
   c. producing the fuels,
   d. transporting the fuels, and
   e. reducing environmental side effects of getting and using the fuels?

Let me know soon!

The Boss

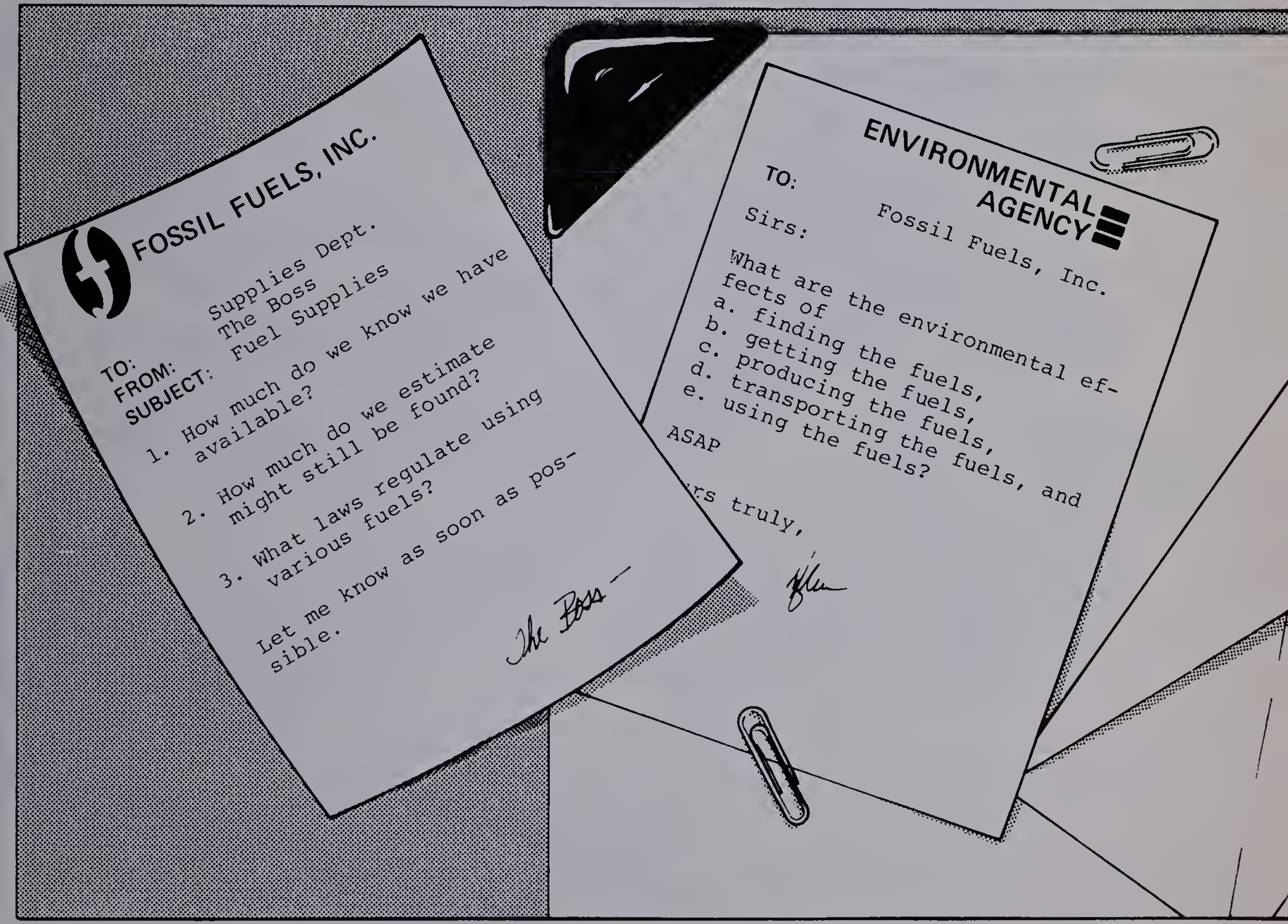
Figure 10-1 (continued on page 49)

Coal is the most plentiful fossil fuel in the United States. The U.S. Geological Survey estimates that at present there are about three hundred and fifty billion tonnes of coal worth mining. That's enough to last a few hundred years at present consumption rates. New mining techniques might open up even more of the total resources.

Most scientists agree that to produce needed energy greater use must be made of the plentiful coal supply. Much of the increased use of coal will be for producing electricity. Figure 10-2 (pages 50 and 51) displays some of the advantages and disadvantages of generating electricity by the use of coal rather than oil or gas.

The estimate of coal reserves may be twenty to fifty percent off.

Underground mines yield about fifty percent of the total coal available within the mine. Strip mines yield between seventy-five and eighty percent of the total coal available in a strippable deposit.



FOSSIL FUELS, INC.

TO: Supplies Dept.
FROM: The Boss
SUBJECT: Fuel Supplies

1. How much do we know we have available?
2. How much do we estimate might still be found?
3. What laws regulate using various fuels?

Let me know as soon as possible.

The Boss

ENVIRONMENTAL AGENCY

TO: Fossil Fuels, Inc.

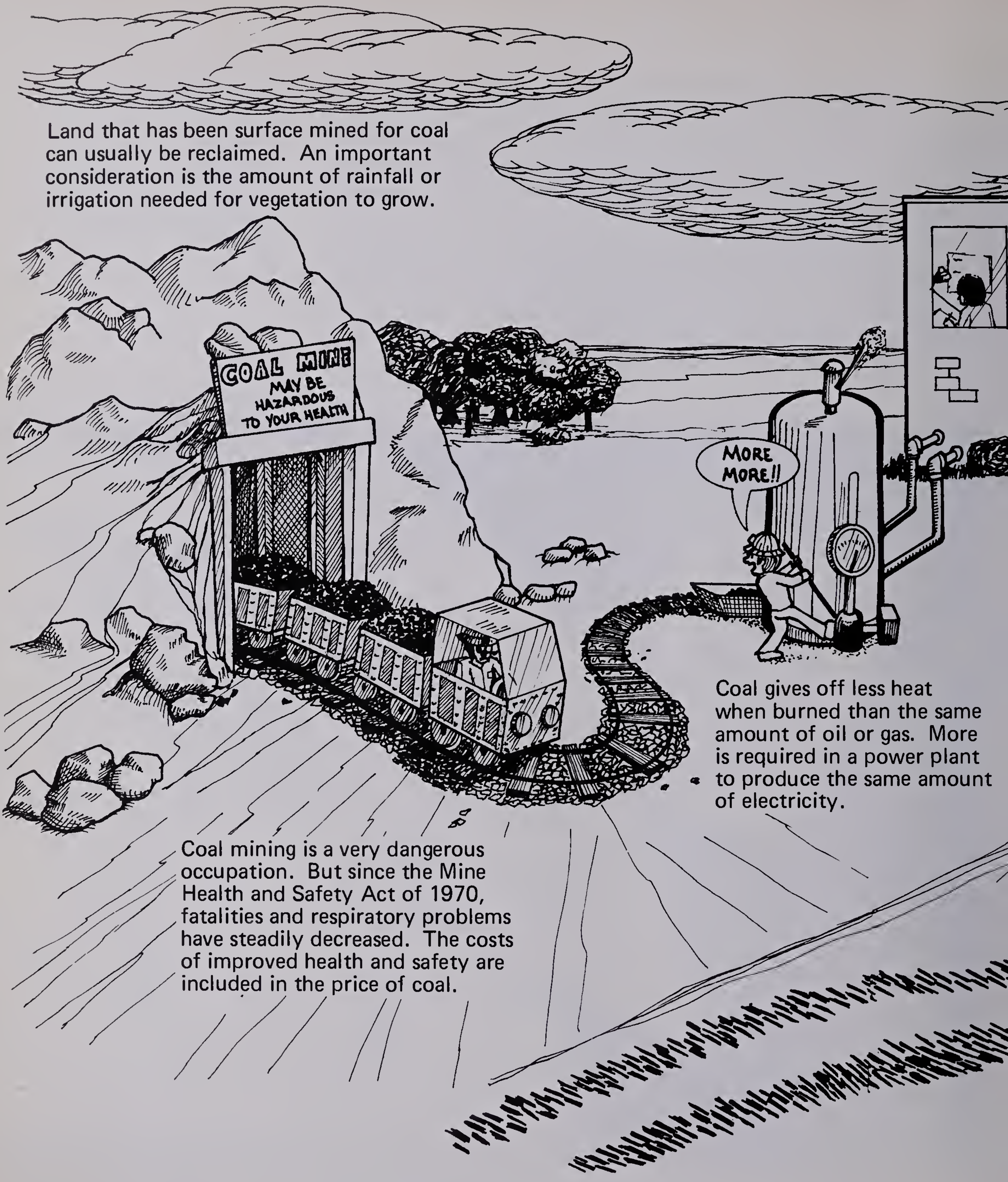
Sirs:

What are the environmental effects of
a. finding the fuels,
b. getting the fuels,
c. producing the fuels,
d. transporting the fuels, and
e. using the fuels?

ASAP

rs truly,

Figure 10-1 (continued from page 48)

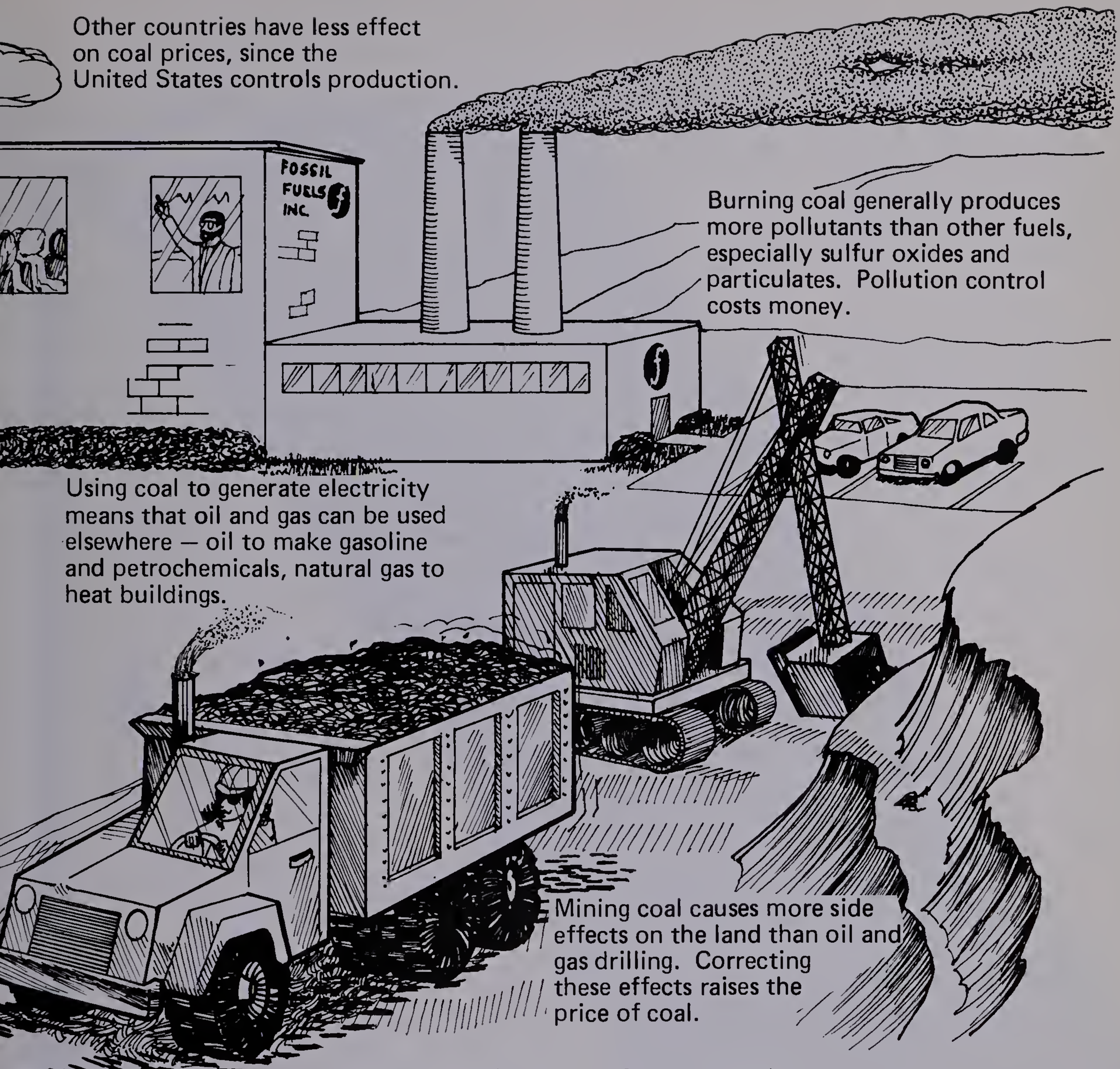


Land that has been surface mined for coal can usually be reclaimed. An important consideration is the amount of rainfall or irrigation needed for vegetation to grow.

Coal gives off less heat when burned than the same amount of oil or gas. More is required in a power plant to produce the same amount of electricity.

Coal mining is a very dangerous occupation. But since the Mine Health and Safety Act of 1970, fatalities and respiratory problems have steadily decreased. The costs of improved health and safety are included in the price of coal.

Figure 10-2 (continued on page 51)


FOSSIL FUELS INC.

Other countries have less effect on coal prices, since the United States controls production.

Burning coal generally produces more pollutants than other fuels, especially sulfur oxides and particulates. Pollution control costs money.

Using coal to generate electricity means that oil and gas can be used elsewhere — oil to make gasoline and petrochemicals, natural gas to heat buildings.

Mining coal causes more side effects on the land than oil and gas drilling. Correcting these effects raises the price of coal.

Figure 10-2 (continued from page 50)

☆ 10-2. In terms of availability, what advantage does coal have over oil and gas as a fuel for electrical power plants?	10-2. More coal than oil or gas is available.
☆ 10-3. What are some of the factors that add to the cost of coal?	10-3. Pollution control, miner health and safety, and land reclamation
☆ 10-4. Oil and gas have a higher heat content than coal. What does that mean?	10-4. Oil and gas produce more heat for the same weight of fuel than coal does.

Advanced

ACTIVITY 11: PLANNING

Activity 12

Page 53

Objective 12-1: Describe the characteristics of the element carbon that permit the formation of so many different carbon compounds.

Sample Question: Which of the following are valid reasons for the existence of so many different carbon compounds?

A. Carbon atoms are basic to all life processes.
B. Carbon atoms bond together to form chains.
C. Carbon atoms can form single, double, or triple bonds.
D. Carbon is the most plentiful element in Earth's crust.

Activity 13

Page 59

Objective 13-1: Define *isomer*, identify examples of isomers, and describe how isomers differ.

Sample Question: If two substances are isomers, which of the following do they have?

A. The same kinds of atoms in their molecules, differently arranged
B. Different kinds of atoms in their molecules, identically arranged
C. Different chemical and physical properties
D. Identical chemical and physical properties

Answers: 12-1. B, C; **13-1.** A, C

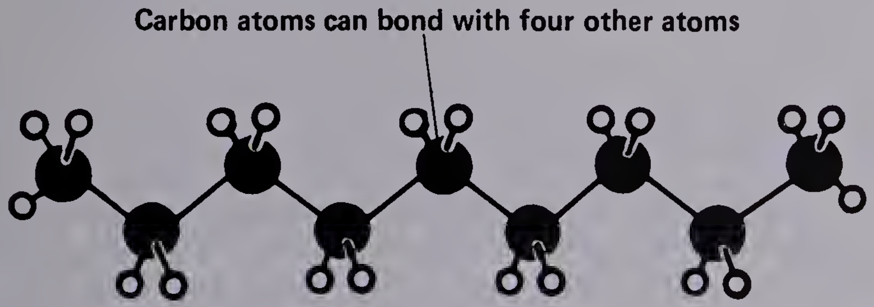
ACTIVITY 12: CHAINS AND THINGS

In your body there are thousands of kinds of molecules, most of them containing carbon atoms. Why are there so many different kinds? That's partly due to the unusual bonding capacity of carbon. This bonding capacity also accounts for the many different carbon compounds found in crude oil and for the millions of carbon compounds in existence.

If you need to review how carbon atoms bond, check "covalent bonds" in the index to *Actions and Reactions*. Then answer Question 12-1 below.

- 12-1. What is a covalent bond?

Carbon is unlike most elements. Its atoms can bond to one another to form huge molecules. Some of these molecules can contain thousands of carbon atoms. And any single carbon atom can be covalently bonded with up to four other atoms, including other carbons.



- 12-2. What is the combining power of carbon when it bonds with four other atoms? (Hint: See *Actions and Reactions* for help.)

The majority of carbon compounds also contain hydrogen. When compounds contain only those two elements – hydrogen, H, and carbon, C – they are called *hydrocarbons*. In the simplest hydrocarbon compound, one carbon atom forms all its four covalent bonds with hydrogen atoms. That compound is called *methane*, CH_4, the main component of natural gas.

A theoretical model of the methane molecule is shown in Figure 12-1 at the right. Notice the positioning of the hydrogen atoms. Each H atom is spaced the same distance from every other H atom and from the central C atom.

- 12-3. Describe the shape of the methane molecule.

ACTIVITY EMPHASIS: There are millions of carbon-containing compounds because carbon atoms form chains, can bond with many other atoms, and can form double and triple bonds.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

12-1. An electron pair shared between two nonmetal atoms

Silicon and a few other elements chain together, but the bonding is neither as extensive nor as stable as with carbon.

If you have them, make molecular model sets available for student use.

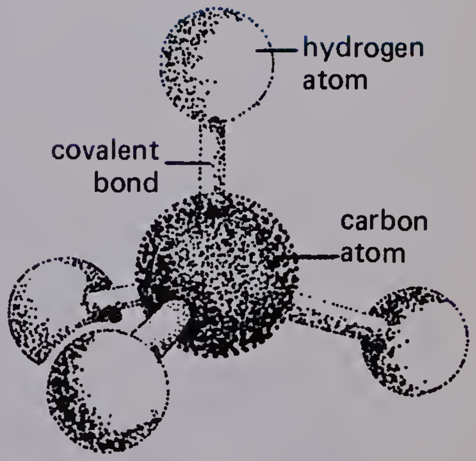


Figure 12-1

12-2. 4

12-3. [Answers will vary. The important point is that the molecule is not flat.]

The four hydrogen atoms form the four corners of what is called a *tetrahedron* — the dotted outline and the solid in Figure 12-2 below left. The carbon atom is in the middle of the tetrahedron.

The next simplest hydrocarbon is *ethane*, C_2H_6. Since it has two carbon atoms and six hydrogen atoms, two tetrahedrons are involved. Look at Figure 12-3 below right. Each carbon is at the center of its own tetrahedron and at one point of the tetrahedron of the carbon next to it.

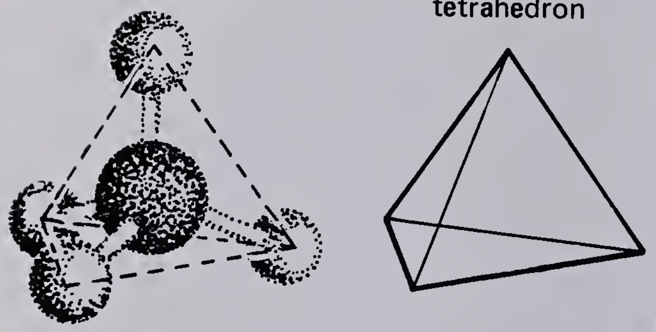


Figure 12-2

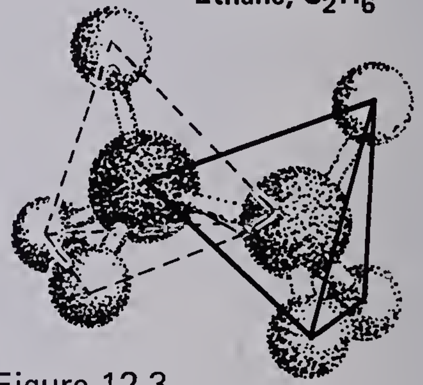


Figure 12-3

- 12-4. In ethane, is each carbon bonded to four other atoms? Explain your answer.

12-4. Yes; each carbon is bonded to three hydrogens and one other carbon.

The three-carbon hydrocarbon is called *propane*, C_3H_8. You might be familiar with this gas, since it's used in torches and some homes. Look at Figure 12-4 below left, showing propane. Notice that the tetrahedral bonding of the carbon affects the shape of the propane molecule. The carbons are linked in a zigzag chain.

Longer chains show this zigzag feature even better. Figure 12-5 below right illustrates a model of nonane, C_9H_{20}.

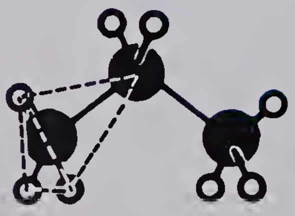


Figure 12-4

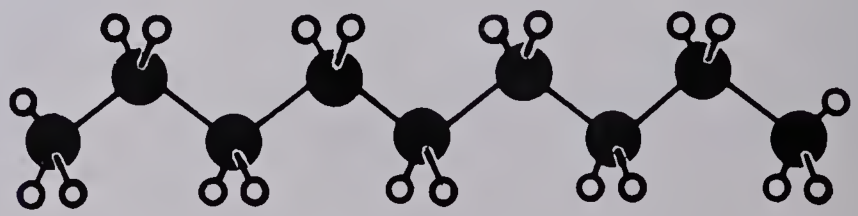
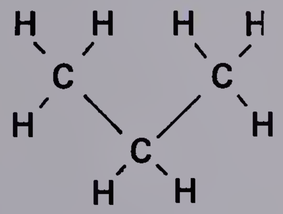


Figure 12-5

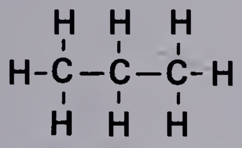
- 12-5. Why are chains of carbon atoms zigzag instead of straight?

12-5. The bonds between carbon atoms are at angles — the tetrahedral bond arrangements.

Because of their tetrahedral bonding arrangement, chains of carbon atoms present a zigzag pattern, not a straight line. It's possible to show this in a diagram. This propane molecule, for example, can be represented as



But that's sometimes a bother, especially with larger molecules containing many carbons. So the general practice in chemistry is to represent such simple chain molecules as *straight chains.* To save time and trouble, you can represent propane as



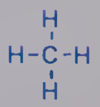
$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

propane, C_3H_8

In this kind of diagram, called a *structural formula*, each line represents a shared pair of electrons — a bond. Such straight-chain diagrams are accurate enough as long as you remember one thing: the carbon "links" in the straight chain actually form tetrahedral (109°) angles with one another. And the H atoms are also attached at tetrahedral angles.

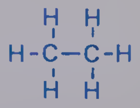
- 12-6. Write the structural formulas for methane and for ethane.

12-6. Methane



$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & H \\ & & | & & \\ & & H & & \end{array}$$

Ethane

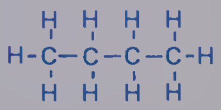


$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

If you continue to draw C atoms and add H atoms to fill up the C bonds, longer and longer chains will result. Each chain will represent a different hydrocarbon with different properties.

- 12-7. Butane gas is often used in camp stoves and lighters. Write the straight-chain structural formula for butane, C_4H_{10}.

12-7.

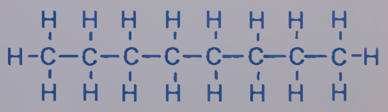


$$\begin{array}{ccccccccccc} & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & \end{array}$$

With four more C atoms added to butane, you have an eight-carbon chain. With the H atoms to satisfy the four bonds of each C atom, this is octane, one of the molecules in gasoline.

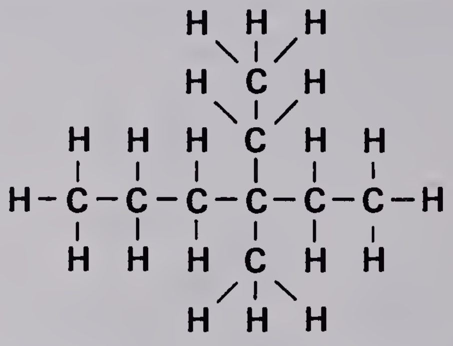
- 12-8. Write the straight-chain structural formula for octane, C_8H_{18}.

12-8.



$$\begin{array}{ccccccccccccccccccc} & & H & & H & & H & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & H & & H & & H & & \end{array}$$

Branched-chain hydrocarbons, with carbons attached to three or more other carbons, also exist. Figure 12-6 below shows the structural formula for one branched-chain hydrocarbon, nonane, C_9H_{20}. Compare it to Figure 12-5 (page 54).



a branched-chain nonane, C_9H_{20}

Figure 12-6

12-9. [Answers will vary; the atom counts should be correct, with bonding capacity of carbon satisfied.]

● 12-9. Write structural formulas for two more branched-chain nonanes, C_9H_{20}.

There are plastics with many hundreds and even thousands of carbon atoms in straight or branched chains. Every difference in the number of carbons and hydrogens, as well as every difference in branching, means a carbon compound with different characteristics.

You could consider rings to be variations of chains.

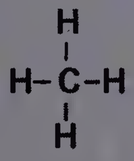
Now you should see that different lengths and types of carbon chains can account for a great many different carbon compounds — and just from atoms of carbon and hydrogen.

12-10. The carbon atoms can bond together in different lengths and types of chains.

☆ **12-10. Why are there so many kinds of hydrocarbons (carbon compounds containing just C and H)?**

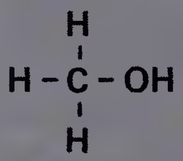
Carbon compounds also exist in which different kinds of atoms or groups of atoms have replaced one or more of the hydrogen atoms in a hydrocarbon. Pages 56 through 58 give structural formulas and descriptions of some of these compounds.

Start with the shortest chain — the one-carbon chain — methane gas, CH_4. With an OH (hydroxyl) group substituted for one of the H atoms you have methyl alcohol, CH_3OH. Methyl alcohol has many uses as a solvent.



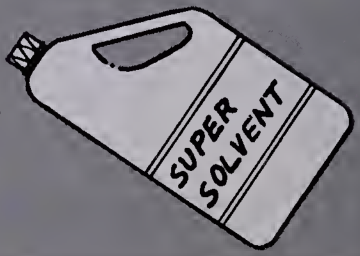
$$\begin{array}{c} H \\ | \\ H-C-H \\ | \\ H \end{array}$$

methane

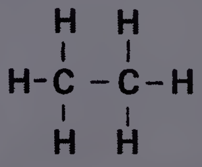


$$\begin{array}{c} H \\ | \\ H-C-OH \\ | \\ H \end{array}$$

methyl alcohol

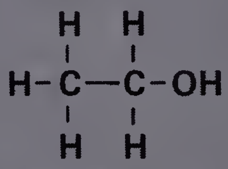


With one OH group substituted for an H atom in ethane, you have ethyl alcohol, C_2H_5OH – the kind in alcoholic beverages. (All alcohols are poisonous, even this one.)



$$\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H- & C & - & C & -H \\ & | & & | & \\ & H & & H & \end{array}$$

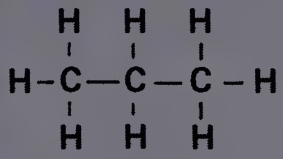
ethane



$$\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H- & C & - & C & -OH \\ & | & & | & \\ & H & & H & \end{array}$$

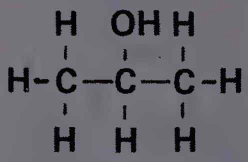
ethyl alcohol

The substitution of an OH group for an H is found in carbon chains of many lengths. With OH substituted for H on the middle carbon of propane, the compound is isopropyl alcohol, often used as rubbing alcohol.



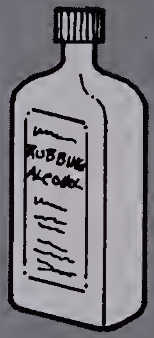
$$\begin{array}{ccccccc} & H & & H & & H & \\ & | & & | & & | & \\ H- & C & - & C & - & C & -H \\ & | & & | & & | & \\ & H & & H & & H & \end{array}$$

propane

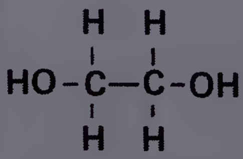


$$\begin{array}{ccccccc} & H & & OH & & H & \\ & | & & | & & | & \\ H- & C & - & C & - & C & -H \\ & | & & | & & | & \\ & H & & H & & H & \end{array}$$

isopropyl alcohol



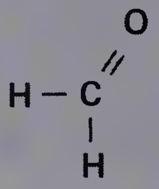
Carbon chains may contain more than one OH group. Ethylene glycol, $C_2H_4(OH)_2$, used for permanent antifreeze, replaces the end Hs of ethane with two OH groups.



$$\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ HO- & C & - & C & -OH \\ & | & & | & \\ & H & & H & \end{array}$$

ethylene glycol

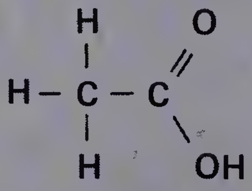
Lone oxygen atoms may also be bonded to carbons. But an O atom forms two bonds, so two H atoms are replaced; and a double bond is formed between the O and C atoms. The simplest compound of this kind is formaldehyde, HCHO. (You may have smelled formaldehyde, since it is used for preserving such things as laboratory frogs.)



$\mathrm{H{-}\underset{H}{C}{=}O}$

formaldehyde

An OH and an O may also be bonded to the same carbon atom. One familiar example is acetic acid, CH_3COOH, the acid in vinegar.

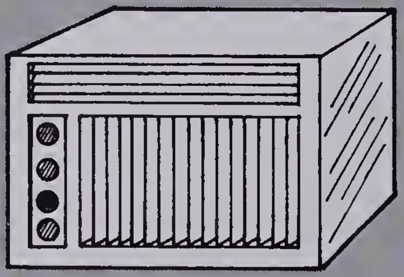


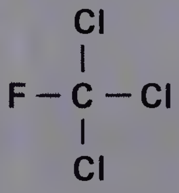
$\mathrm{H{-}\underset{H}{\overset{H}{C}}{-}C({=}O){-}OH}$

acetic acid

Many other kinds of atoms may replace some of the H atoms in a carbon chain. With atoms of chlorine, Cl, and fluorine, F, substituted for the H atoms of methane, you have one of the freon gases used in the cooling units of refrigerators and air conditioners. Until recently, freon gases were also used as propellants in some aerosol spray cans.

Use of ozone-destroying chlorofluorocarbons has been greatly restricted by recent government regulations.





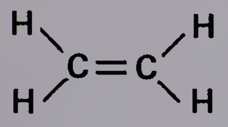
$\mathrm{F{-}\underset{Cl}{\overset{Cl}{C}}{-}Cl}$

freon

12-11. It helps explain why there are so many carbon compounds.

☆ 12-11. Carbon atoms in chains can bond with such atoms as O or Cl, or such a group as OH. How does this fact relate to the number of existent carbon compounds?

All the carbon-carbon bonds you've seen have been single bonds. But carbon atoms also have the capability to get together in double or triple bonds. Carbon compounds with these bonds are called *unsaturated.* The simplest unsaturated carbon compounds are ethylene, used to make polyethylene, and acetylene, used in acetylene torches.



ethylene

$H-C\equiv C-H$

acetylene

Oleic acid, $C_{17}H_{15}COOH$, with one double carbon-carbon bond, is an unsaturated fatty acid made from animal fats and vegetable oils. Natural fats and oils with more than one such bond are termed *polyunsaturated.* You may have heard this expression on TV commercials.

☆ **12-12. Carbon atoms can bond together to form chains. They also form bonds with other kinds of atoms. What is the third reason for the existence of so many different carbon compounds?**

12-12. Carbon atoms can form double or triple bonds with other carbon atoms.

ACTIVITY 13: TWINS AND NOT TWINS

ACTIVITY EMPHASIS: Isomers are substances whose molecules have the same kind and numbers of atoms but in different arrangements. The chemical and physical properties of isomers are different.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

Both molecules shown in Figure 13-1 below are found in gasoline. Count the carbon and hydrogen atoms shown in Molecule A and in Molecule B.

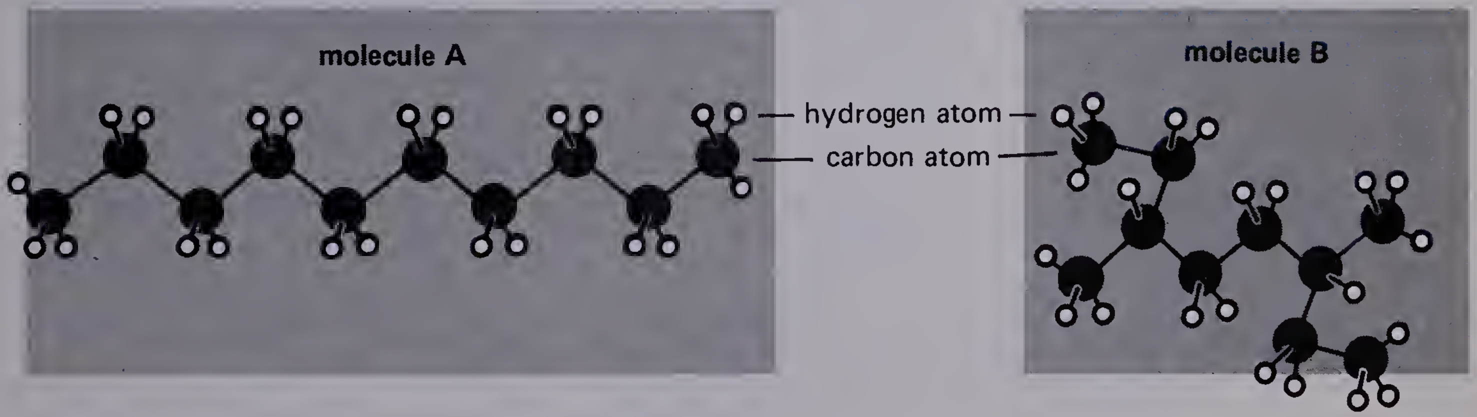
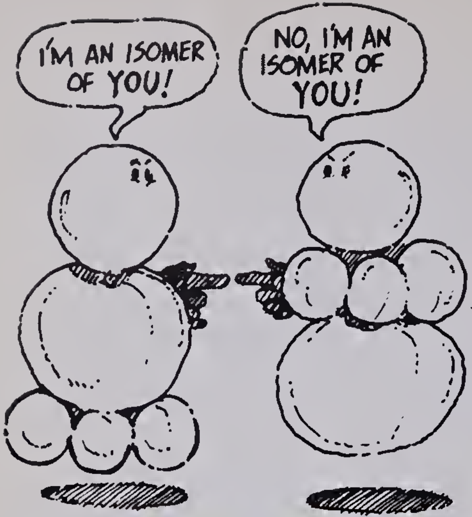


Figure 13-1

- 13-1. How many atoms of carbon are there in Molecule A and in Molecule B? How many atoms of hydrogen are there in each?

13-1. 10 in each; 22 in each


I'M AN ISOMER OF YOU!
NO, I'M AN ISOMER OF YOU!

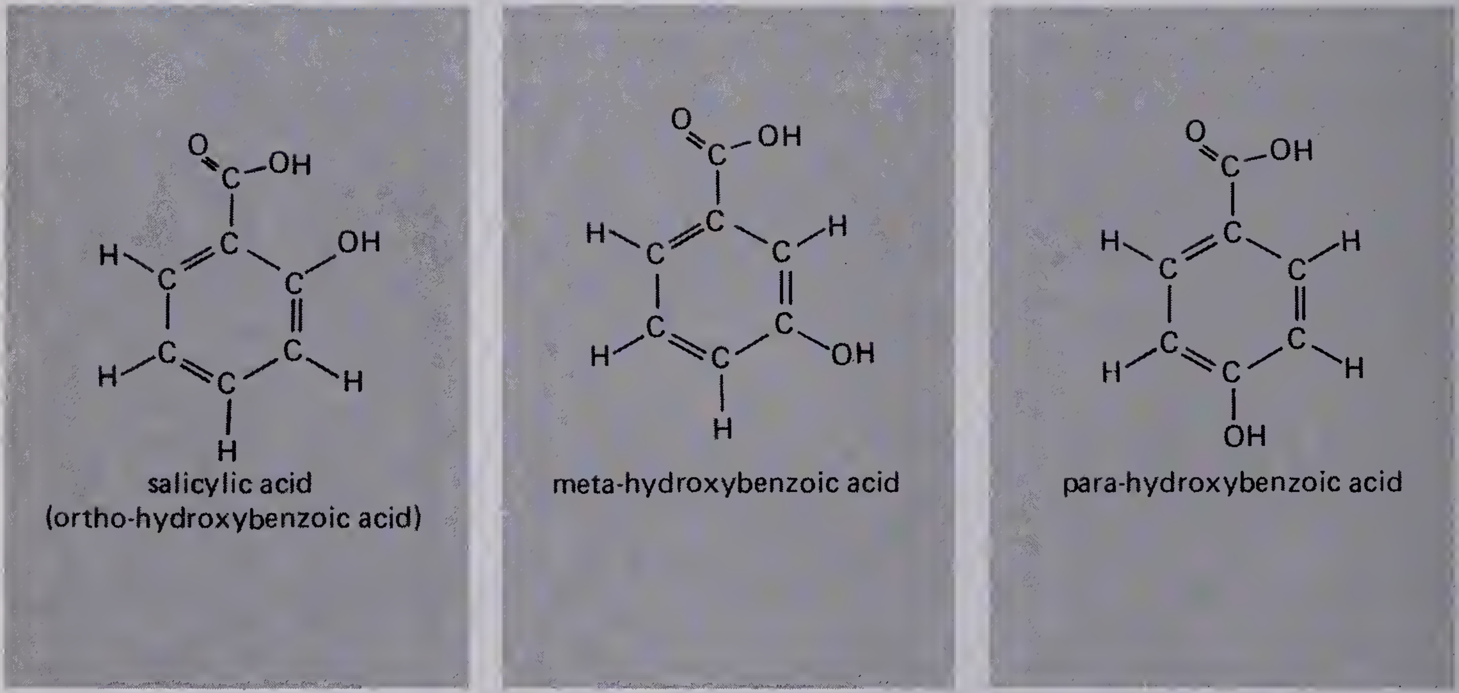
13-2. They have the same number and kinds of atoms; the atoms are arranged differently.

You can see that for atom-counting purposes the two molecules are the same. They are *isomers* of each other. Isomers are like twins – sort of chemical twins. They have the same numbers of each kind of atom, but arranged differently.

☆ **13-2. How are isomer molecules like each other? How are they unlike?**

Because their atoms are differently arranged, the isomer molecules have different chemical and physical properties. For example, the two gasoline isomer molecules shown in Figure 13-1 (page 59) burn differently in the same automobile engine.

Let's look at another example. Figure 13-2 below shows three molecules. Study them carefully.


salicylic acid (ortho-hydroxybenzoic acid)

meta-hydroxybenzoic acid

para-hydroxybenzoic acid

Figure 13-2

13-3. There are seven carbon atoms, six hydrogen atoms, and three oxygen atoms in each molecule.

● 13-3. How many carbon atoms are in each molecule in Figure 13-2 above? How many hydrogen atoms? How many oxygen atoms?

13-4. Yes; they have the same number and kinds of atoms arranged differently.

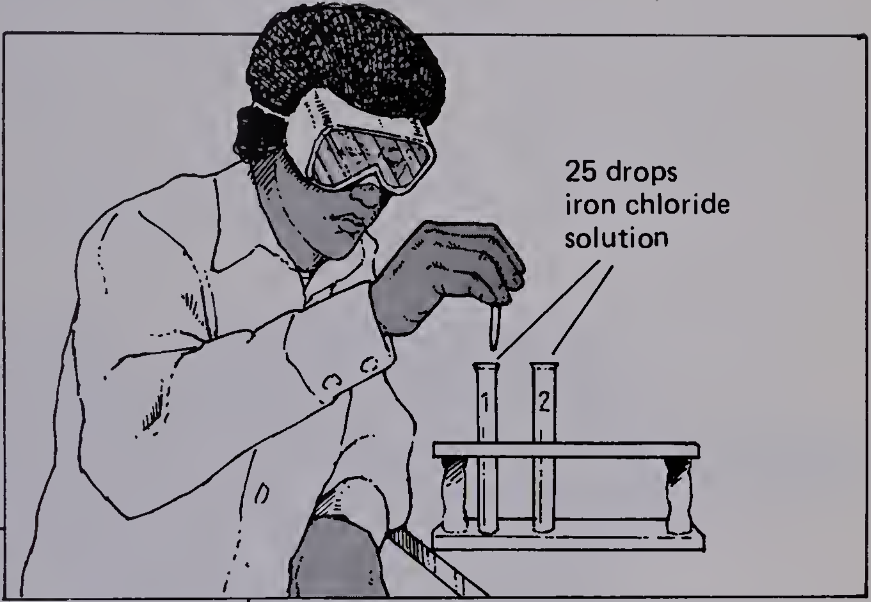
☆ **13-4. Study the three molecules shown in Figure 13-2. Are they isomers? Explain your answer.**

Since the atoms in those compounds are arranged differently, the compounds should have different chemical properties. You can check this with an investigation that will take about twenty minutes.

You will need the following materials.

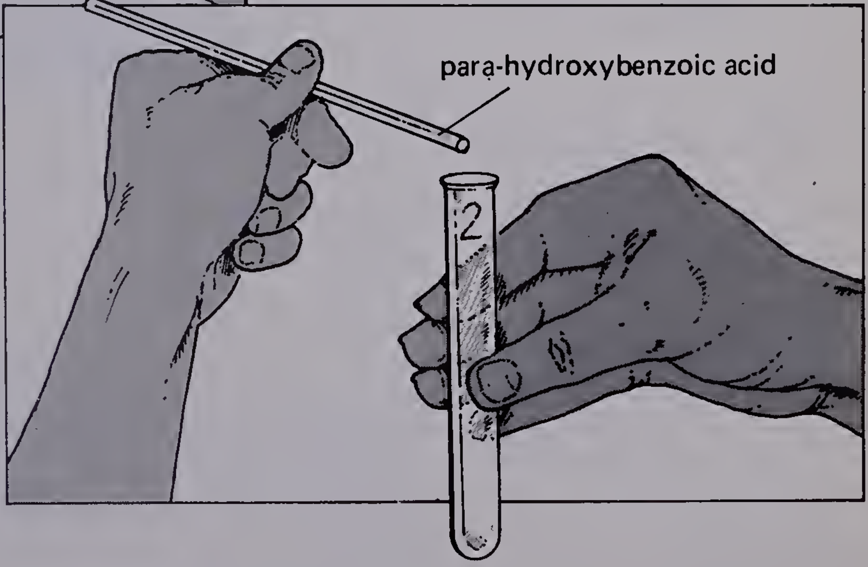
safety goggles
2 test tubes
test-tube rack
2 soda straws
salicylic acid
para-hydroxybenzoic acid
solution of iron(III) chloride, 0.1M, in a dropping bottle
grease pencil

A. With the grease pencil, label the test tubes *1* and *2*. Put about 25 drops of the iron chloride solution into each tube.



B. With one of the soda straws, take a few crystals of salicylic acid from the bottle. Put the crystals into Test Tube 1. Swirl the tube to mix the contents.

C. Using the other straw, add a few crystals of the para-hydroxybenzoic acid to Test Tube 2. Swirl the contents to mix them.



13-5. The substance in Test Tube 1 turned dark red. The substance in Test Tube 2 turned pale yellow.

● 13-5. Describe what happened in each test tube.

Meta-hydroxybenzoic acid is very expensive compared to its two isomers — salicylic acid and para-hydroxybenzoic acid. Thus, it is not available for you to test.

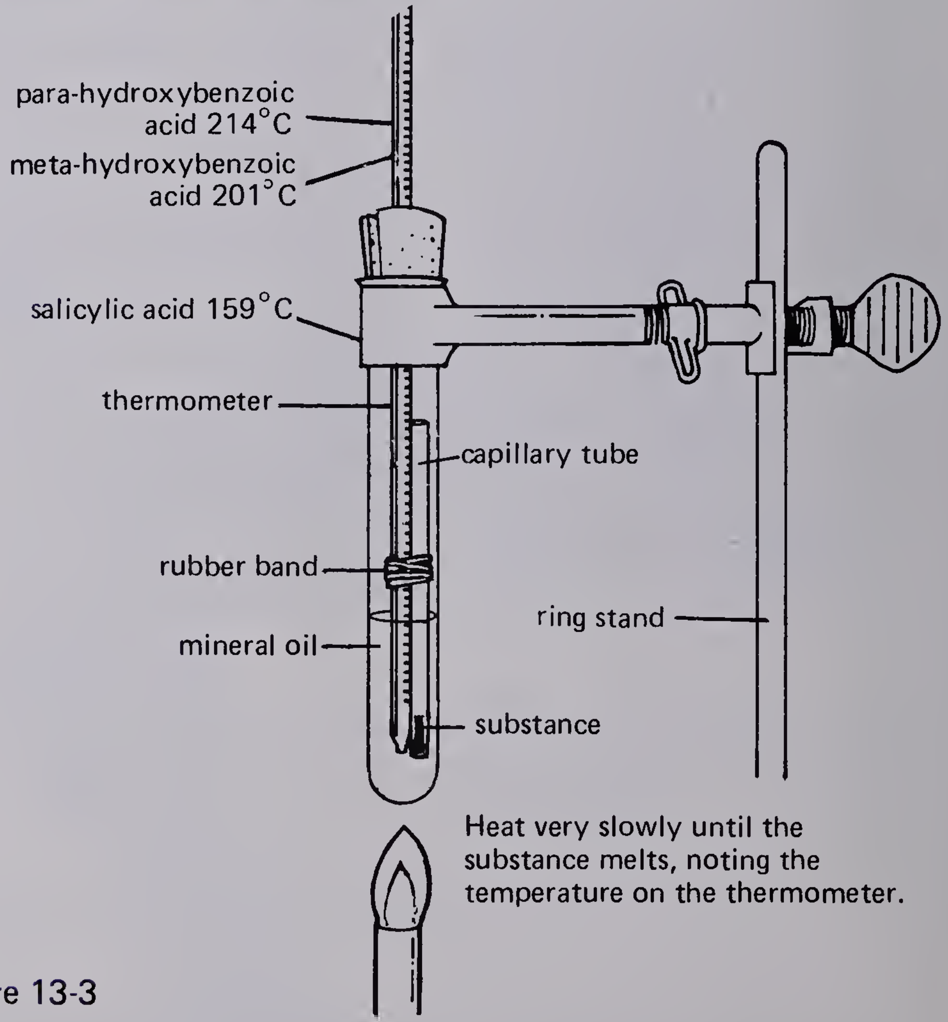
13-6. Different

● 13-6. Suppose you could test the meta-hydroxybenzoic acid with iron(III) chloride. Would you predict the results of your test to be different from or the same as your tests with salicylic acid and para-hydroxybenzoic acid?

13-7. Different

☆ 13-7. Are the chemical properties of isomers the same or different?

The physical properties of these three substances (such things as melting and boiling points) are different also. Look at the melting-point apparatus shown in Figure 13-3 below.



Heat very slowly until the substance melts, noting the temperature on the thermometer.

Figure 13-3

If you have melting-point apparatus, you may want students to check those data. You could also have students make models of isomers, like octane and isooctane.

13-8. Different

☆ 13-8. Are the physical properties of isomers the same or different?

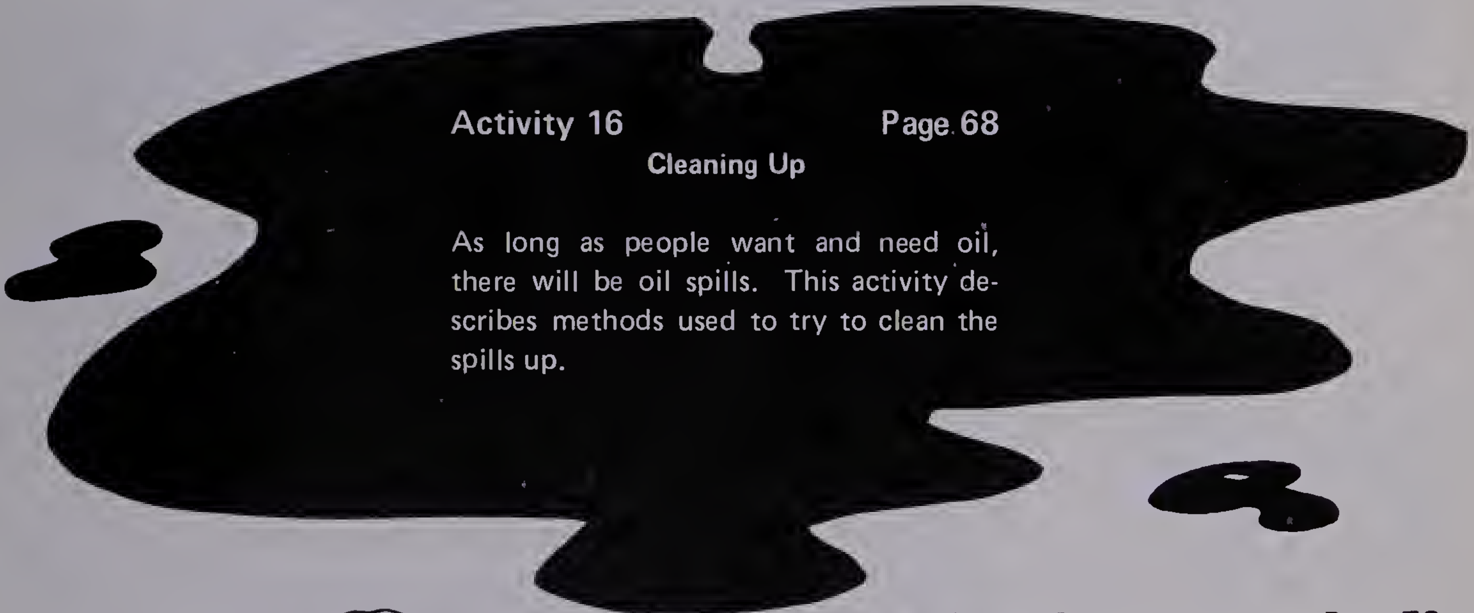
EXCURSION

ACTIVITY 14: PLANNING

Activity 15 **Page 64**

Fuel from Recycling

Did you know that you can get fuels from waste materials? In this activity, you'll learn about two different ways to do that. You'll try one of them. And, while you're at it, you should be able to burn the gas you make.



Activity 16 **Page 68**

Cleaning Up

As long as people want and need oil, there will be oil spills. This activity describes methods used to try to clean the spills up.

Activity 17 **Page 72**

Shale, Shale, the Oil's Right Here

In this activity you can do the practically impossible – get fuel from a piece of rock!

ACTIVITY EMPHASIS: Pyrolysis and fermentation are two methods of producing fuels from waste materials and garbage.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

ACTIVITY 15: FUEL FROM RECYCLING

When the sanitation workers pick up your trash and garbage, what becomes of it? If your town is like most towns and cities in North America, one of two things happens. Either the garbage is incinerated in large furnaces or it is taken to a dump or "sanitary land fill" and buried. (It may be burned in the open air first.)

WHAT DO YOU DO WITH 20 MILLION TONS OF GARBAGE?

Both of these methods can cause environmental problems. Both use energy (usually from fossil fuels) and contribute to pollution. But now a new method of processing wastes is coming into use.

This method is called pyrolysis [pie-RAHL-ih-sis]. In it, organic wastes like garbage, paper, and plastics are strongly heated in the absence of oxygen. They give off gases that are then recycled into the heating unit. As the pyrolysis process goes on, it becomes partly self-fueling. And the amount of waste to dispose of is greatly reduced (compared to burned or buried waste).

To see how the pyrolysis process works, you'll need about twenty minutes, a partner, and the following materials.

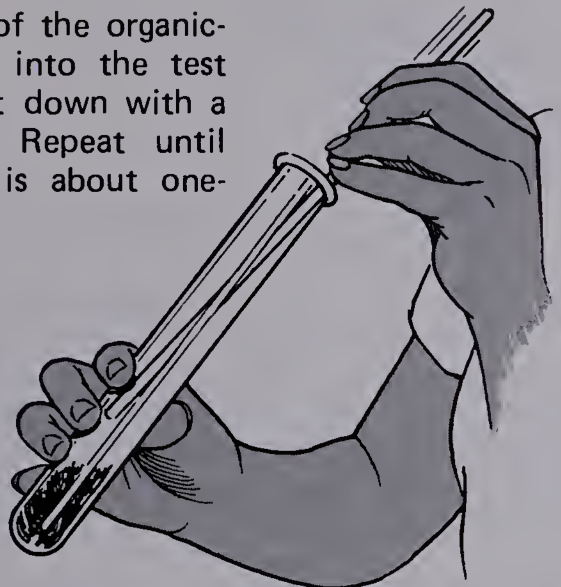
safety goggles
ring stand
utility clamp
Bunsen burner
pyrolysis test-tube and stopper assembly
alcohol
organic-waste mixture (about ½ test tube)
narrow spatula
stirring rod
wood splints

CAUTION Do this investigation in a well-ventilated area. Wear your safety goggles to protect your eyes.

You might want to have some students try weighing the test tube empty, full, and after pyrolysis.

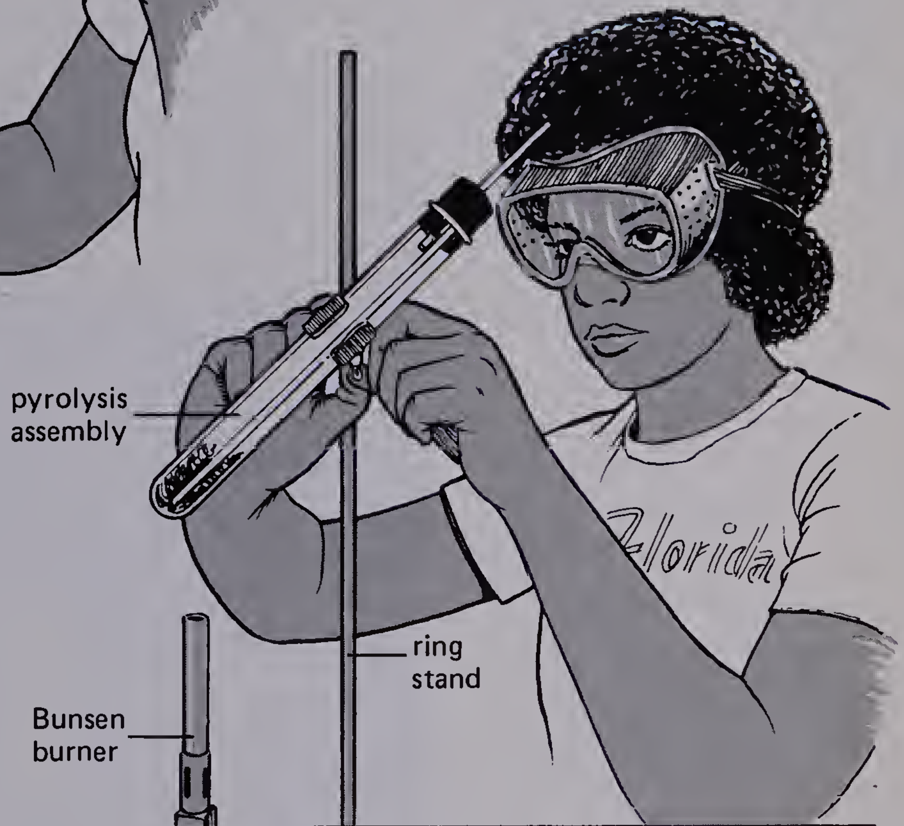
If the gases pass off too vigorously to keep the splint lit, suggest more moderate heating. You might also increase nozzle aperture.

A. Put a little of the organic-waste mixture into the test tube. Tamp it down with a stirring rod. Repeat until the test tube is about one-third filled.



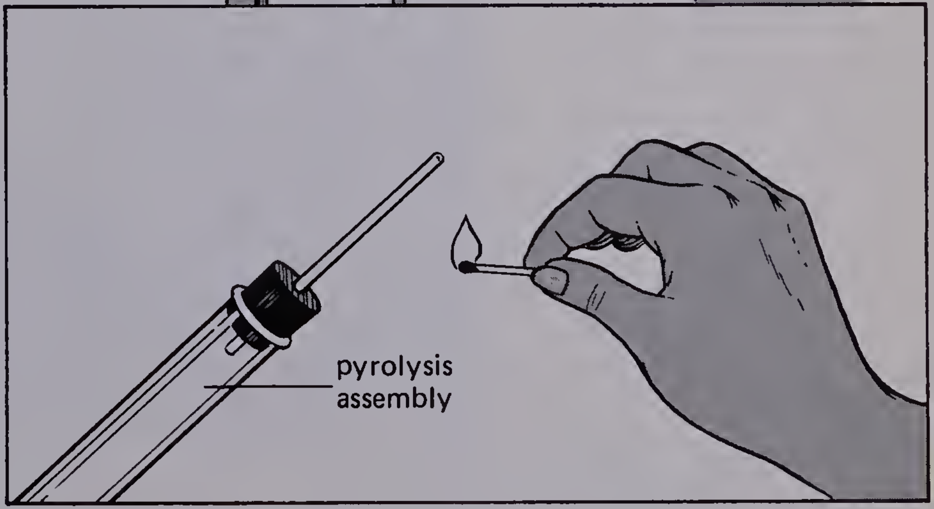
B. Clamp this filled pyrolysis assembly on the ring stand at an angle as shown.

C. Light the burner. Heat the assembly gently at first, then more strongly, by moving the burner back and forth along the bottom. Observe what happens inside the test tube.



D. Have your partner use a burning wood splint to ignite the gases as they leave the tube. Try to keep a flame going.

E. When no more gases are produced, allow the pyrolysis assembly to cool.



F. Scrape out the residue and dispose of it properly. Rinse out the tube with a little alcohol. Return the items of equipment to their proper places.

15-1. [Answers will vary; students should have been able to ignite the gases produced at some time.]

- 15-1. Describe the results of your pyrolysis investigation.

Pyrolysis decomposes the materials that are being strongly heated. But without oxygen, there is no burning. So the gases from the decomposition are just driven off. What's left is a charcoallike residue. The entire process is diagrammed in Figure 15-1 below.

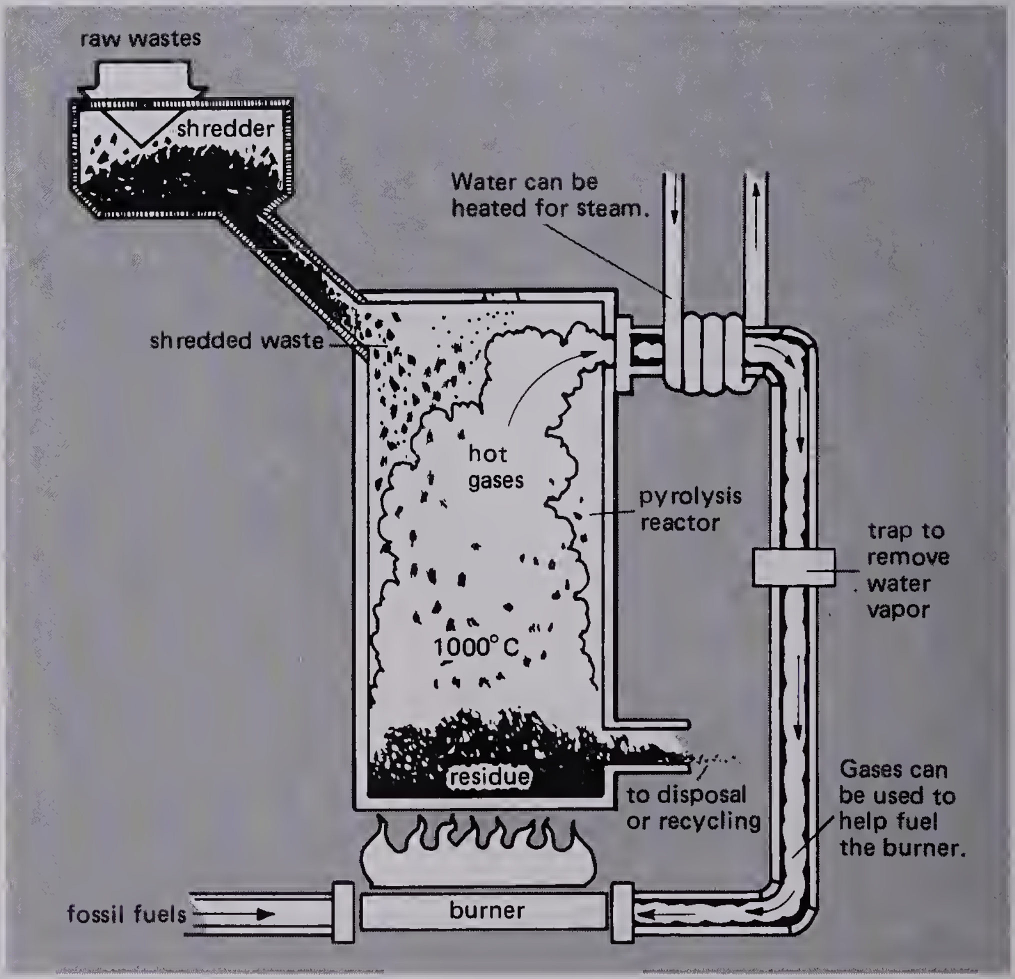


Figure 15-1

Treating wastes by pyrolysis has several advantages over burning or burying them. First, once water vapor has been removed the gases can help fuel the process themselves. This reduces the need for fossil fuels. Second, the amount of disposable wastes is less than before. (Your investigation should have shown you that.) Third, because the solid waste isn't burned there's less air pollution. And finally, heat from the process can be used to make steam for boilers or generators.

☆ **15-2. How does pyrolysis produce burnable gases?**

15-2. The strongly heated materials decompose and gases are driven off.

☆ **15-3. Describe two ways in which pyrolysis is useful.**

15-3. Two of the following: produces gases which can be used to help fuel the process; reduces the amount of waste to be disposed of; supplies heat to produce steam; reduces pollution.

Another process, called *fermentation*, makes use of garbage to produce fuel. Instead of heat, microorganisms are used to break down the garbage. The garbage is slowly decomposed by the microorganisms. Burnable gases and liquids result. Look at Figure 15-2 below.

Methane, ethanol, and other compounds can be produced during anaerobic decomposition of organic material.

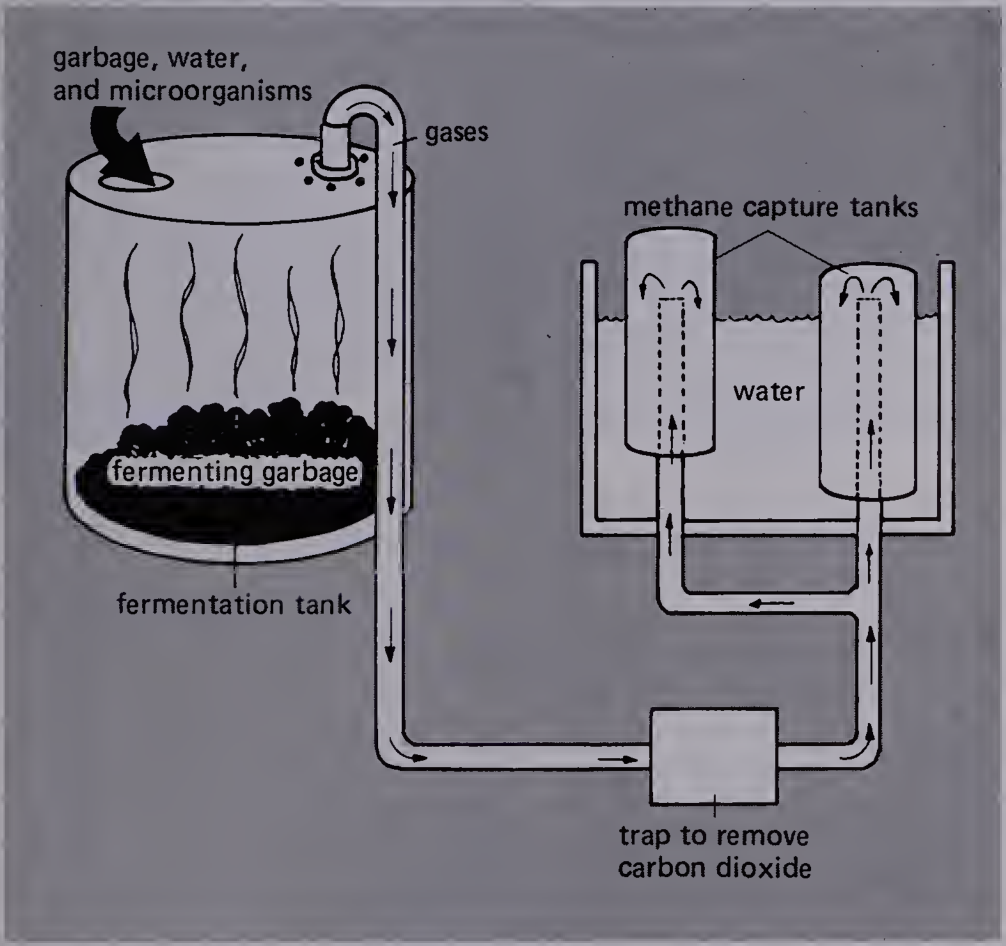


Figure 15-2

☆ 15-4. How does fermentation produce fuels?

15-4. Microorganisms break down garbage to produce fuels.

ACTIVITY EMPHASIS: Students can try cleaning up oil spilled on water. An oil spill must be controlled, picked up, then cleaned up.

ACTIVITY 16: CLEANING UP

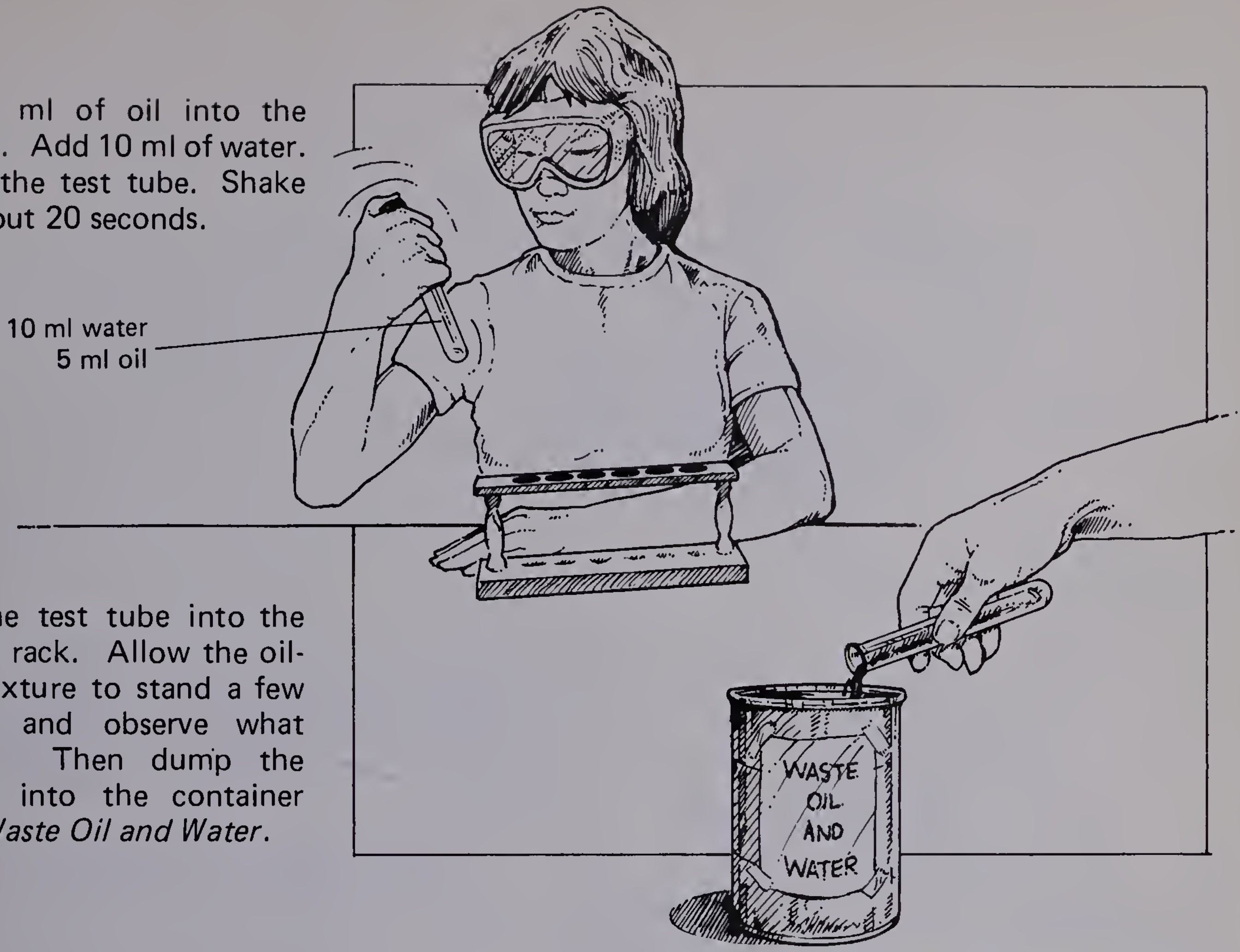
No one wants oil-spill disasters, especially not the oil companies, who lose valuable oil and face high costs for cleaning up. But oil spills happen anyway. The problem, then, is how to clean them up afterward.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

Try cleaning up a miniature oil spill on water. You'll need about fifteen minutes, a partner, and the following materials.

safety goggles
wood strip marked *Activity 16*
aluminum pan, rectangular
test tube with stopper
test-tube rack
oil
spoon
10 cm X 10 cm piece of cotton cloth
tongue depressor
detergent
small graduated cylinder
Waste Oil and Water container

A. Put 5 ml of oil into the test tube. Add 10 ml of water. Stopper the test tube. Shake it for about 20 seconds.



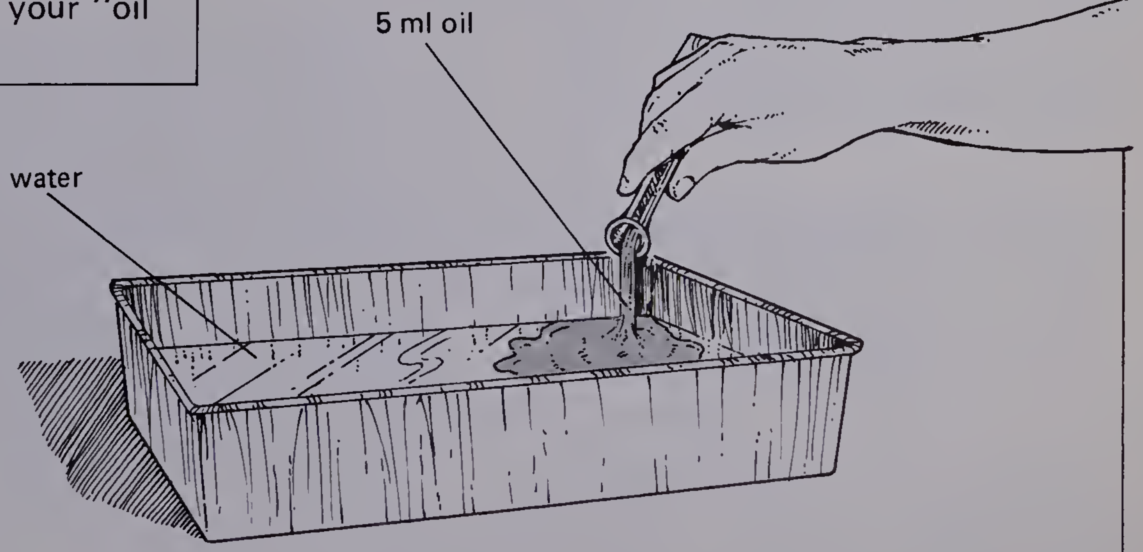
B. Put the test tube into the test-tube rack. Allow the oil-water mixture to stand a few minutes, and observe what happens. Then dump the contents into the container labeled *Waste Oil and Water.*

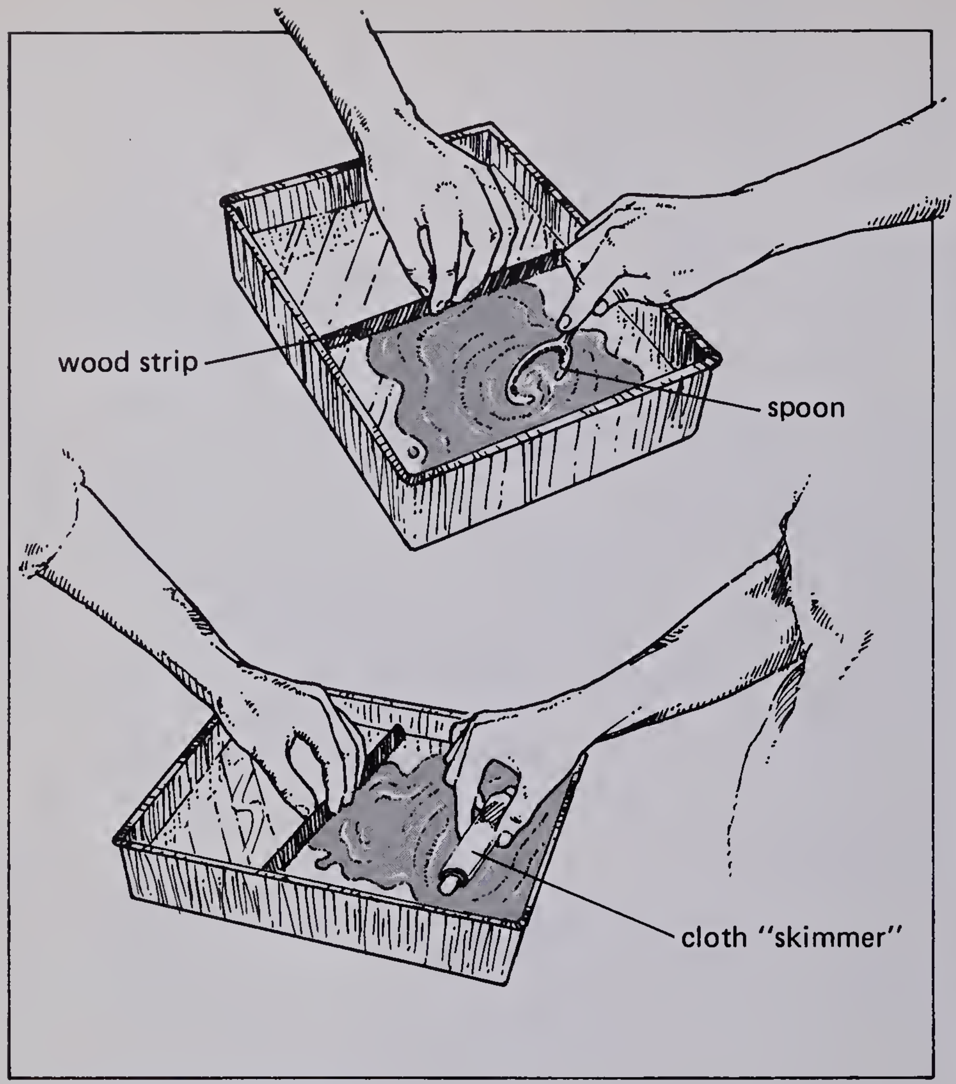
Use a waste container rather than dumping the oil down the drain.

- 16-1. What happened to the oil-water mixture after you allowed it to stand for a few minutes? Where does the oil end up?

16-1. The mixture separated. The oil went to the top and the water to the bottom.

C. Fill the pan half full of water. Pour in about 5 ml of oil. This represents your "oil spill."

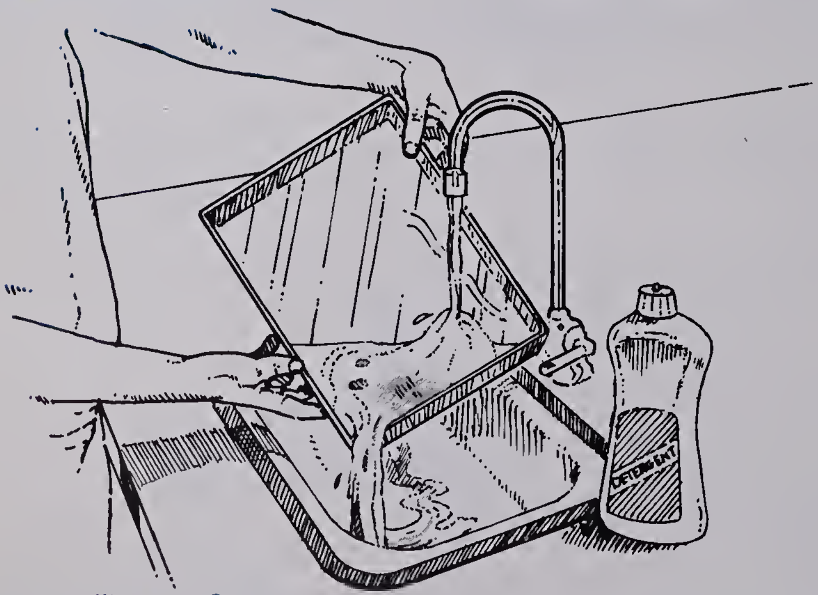




D. Have your partner use the wood strip to contain the spread of the oil in one end of the pan. Then you use the spoon to pick up as much oil as possible. Dump the oil into the *Waste Oil and Water* container.

E. Next, wrap the cloth strip around a tongue depressor. With your partner still controlling the oil, collect the remainder by rolling the cloth strip along the surface of the water. Oil should come to the upper part of the cloth as you roll it around. Use your finger to scrape this oil into the *Waste Oil and Water* container.

Polypropylene fibers matted together are used in skimmers.



F. Put a little detergent in the pan water. Then flush the mixture down the drain. Clean up all other equipment. Use detergent and hot water (if available).

16-2. [Answers will vary. Some oil was probably left on the water in the pan.]

- 16-2. How successful were you in cleaning up your "oil spill"? Describe the results of your efforts.

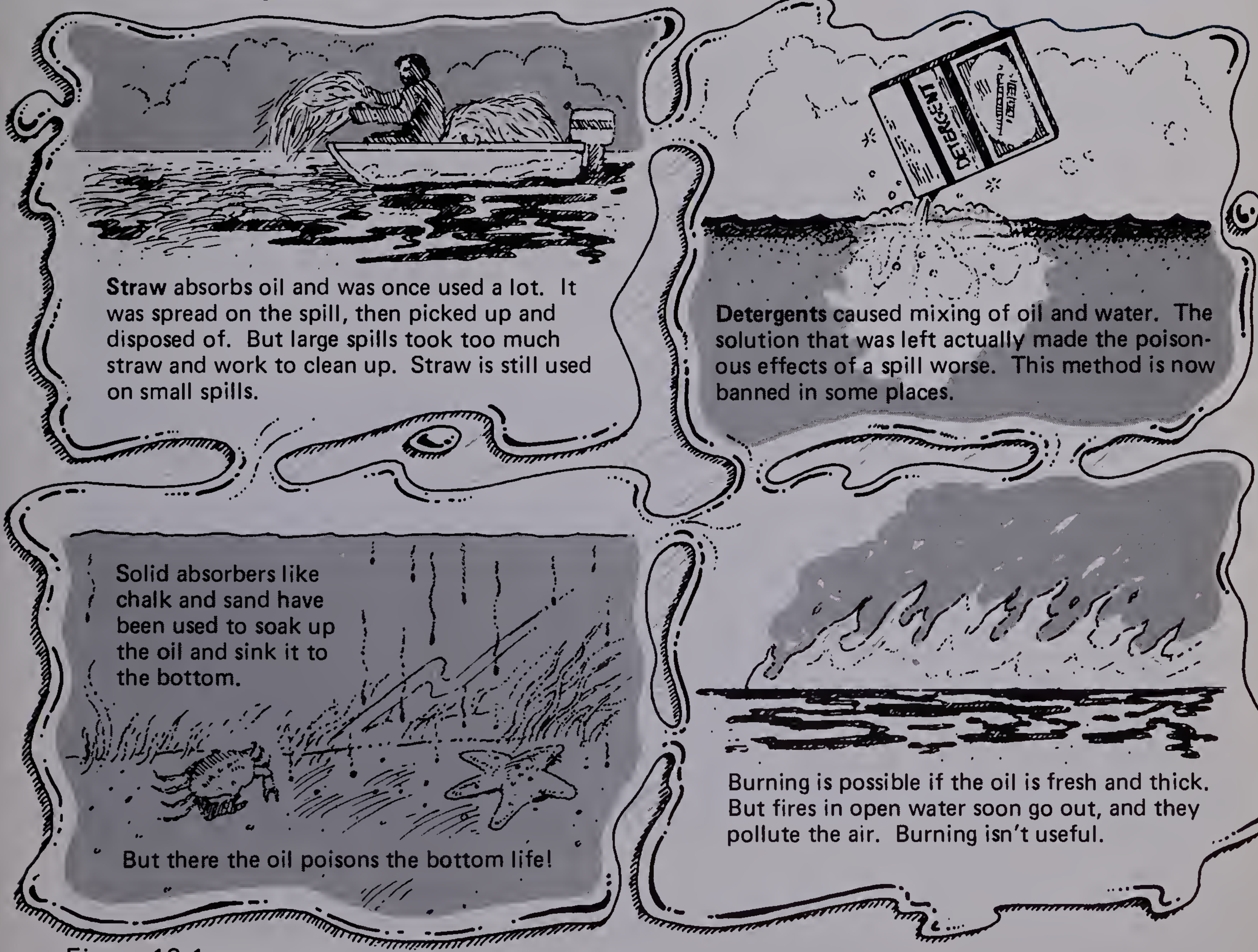
Real oil spills are difficult and expensive to clean up. The approach used depends on the condition of the water (calm or rough) as well as the size of the spill (small or large). In rough water the first job is to keep the spill together until the water calms. Large spills can be held together somewhat by chemicals. Small spills usually get quickly mixed up in the water.

Once the water's calm, a small spill (if it's still together) can be cleaned up fairly well. Often what's used is a *skimmer* — a mechanical device using some kind of oil-absorber.

A large spill must first be contained — kept from drifting and spreading. Floating booms are often placed around the spill. Most of the oil can then be pumped from the surface into tankers. The remainder is removed with a skimmer.

A variety of other methods have been tried, with generally poor success (Figure 16-1 below).

Use of detergents on the *Torrey Canyon* spill led to devastating effects on Britain's coastline.



Straw absorbs oil and was once used a lot. It was spread on the spill, then picked up and disposed of. But large spills took too much straw and work to clean up. Straw is still used on small spills.

Detergents caused mixing of oil and water. The solution that was left actually made the poisonous effects of a spill worse. This method is now banned in some places.

Solid absorbers like chalk and sand have been used to soak up the oil and sink it to the bottom.

But there the oil poisons the bottom life!

Burning is possible if the oil is fresh and thick. But fires in open water soon go out, and they pollute the air. Burning isn't useful.

Figure 16-1

16-3. Containing the oil, pumping most off, then removing the remainder with a skimmer

☆16-3. What are the three steps now used in cleaning up a large oil spill in calm water?

There is continuing research on ways to clean up large spills. One promising method might be used on tankers in accidents. If they are just starting to break up and spill oil, chemicals can be added to the leaking oil. This turns the oil into a gelatinlike mass that leaks more slowly and can be cleaned up more easily.

As long as people want and use oil, spills will happen — even with the most careful precautions. Efforts to prevent and clean up spills, and to reduce their effects, are vital.

16-4. Pumping it off; using a skimmer; using straw to absorb it

☆16-4. Describe three useful ways of removing oil from water.

ACTIVITY EMPHASIS: The crushing and strong heating of oil shale releases fossil fuel gases and liquids. Disposal of the wastes is a major drawback of the process.

ACTIVITY 17: SHALE, SHALE, THE OIL'S RIGHT HERE

Inside shale rock deposits in Wyoming, Colorado, and Utah is a lot of captive energy. This "oil shale" contains the recoverable equivalent of as much as 54 billion barrels of oil!

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

One way to recover this energy is to crush the oil shale and heat it to 500°C. Then gases and oily liquids are driven off. They are fossil fuels.

You can see this for yourself. Get the following materials.

safety goggles
sample of oil shale
mortar and pestle
steel wool
asbestos pad
Bunsen burner
test tube
stopper and glass tube to fit test tube
ring stand
utility clamp
tongs
strip of paper
safety matches
wood splint

CAUTION Wear your safety goggles to protect your eyes. You are going to make a flammable fuel. Go to the special area set aside by your teacher for this investigation. Find the fire extinguisher nearest you. Learn how to use it.

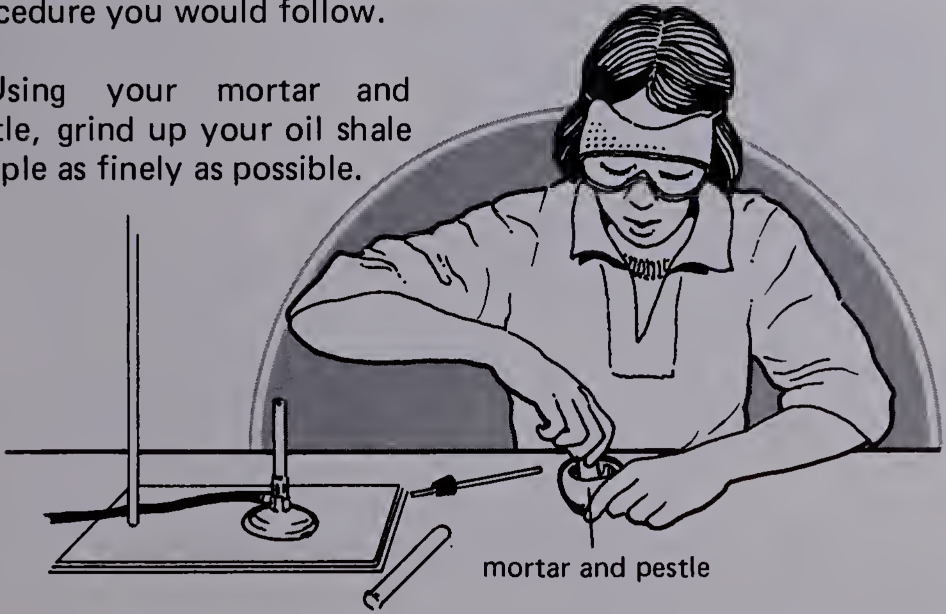
Set aside a well-ventilated work area (fume hood if possible) that is free of combustible materials and has a CO_2 or dry powder foam fire extinguisher nearby.

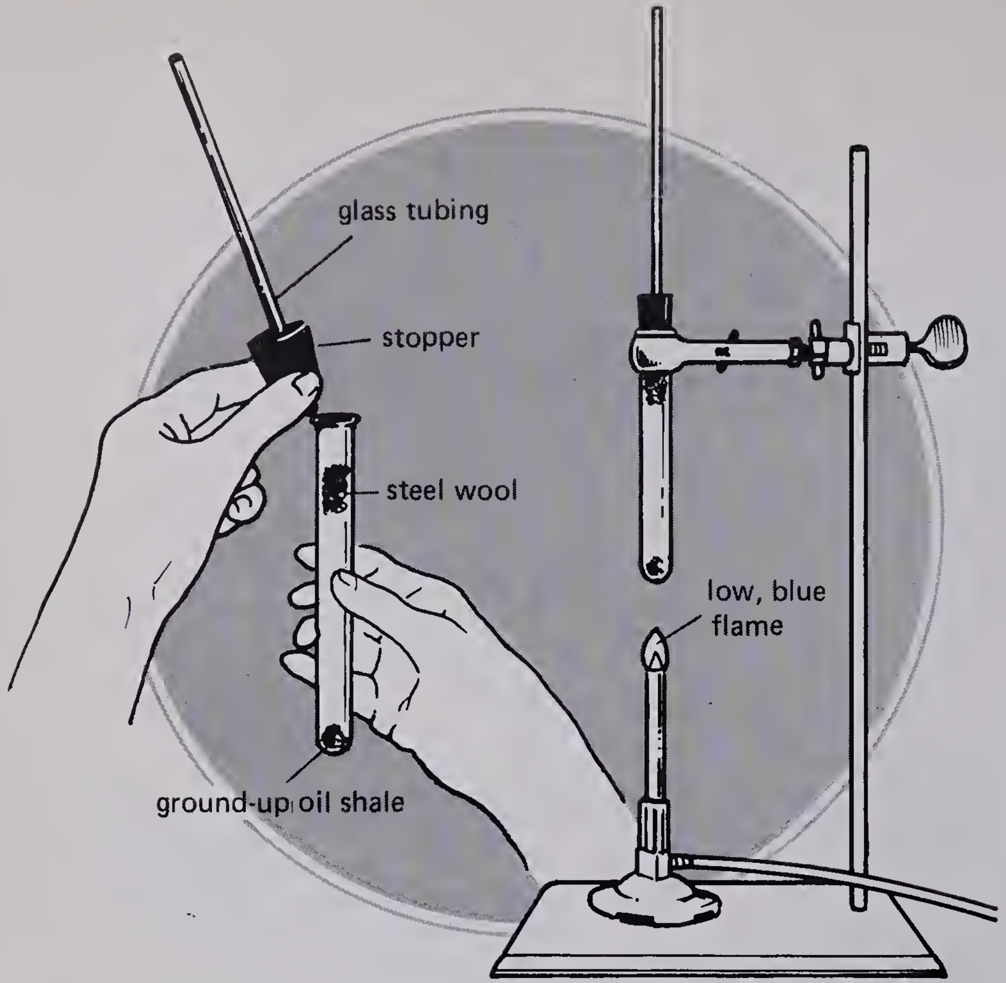
Are you uncertain how to use the burner? If so, read "Resource Unit 17: Using a Burner" before going on.

- 17-1. Suppose something accidentally caught fire during this investigation. What would you do? Write a description of the procedure you would follow.

17-1. [Answers will vary, but should include the following: Get the fire extinguisher and put out fire, report fire to teacher.]

A. Using your mortar and pestle, grind up your oil shale sample as finely as possible.





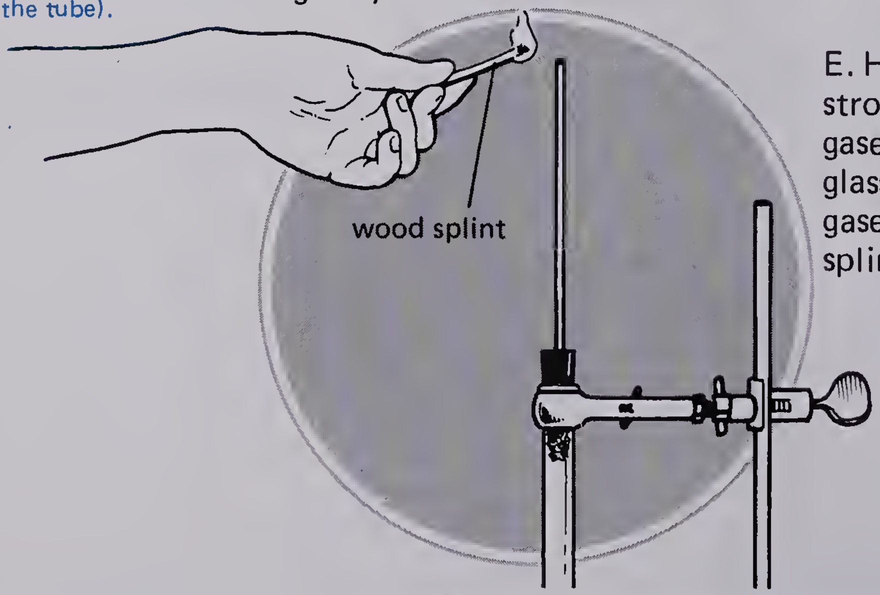
B. Put the ground-up oil shale into the test tube. Put a tuft of steel wool into the top of the test tube. Then insert the stopper and glass-tube assembly.

C. Clamp the test tube onto the ring stand in an upright position. Attach it high enough so that the burner can fit easily underneath.

D. Light the burner, and set it for a low, blue flame. Put it under the test tube. Heat the oil shale gently, and observe what happens.

17-2. It became cloudy inside (a dark liquid may have condensed on the side of the tube).

- 17-2. What happened inside the tube as the oil shale was gently heated?



E. Heat the test tube more strongly. Heat until the cloudy gases rise and come out of the glass tube. Try lighting the gases with a burning wood splint. Keep them burning.

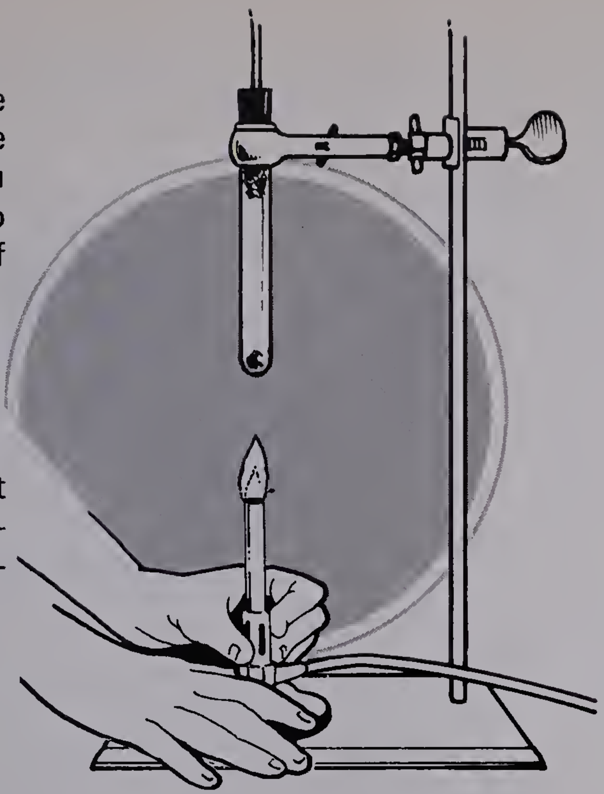
17-3. A liquid is condensing on the side walls of the tube.

- 17-3. What do you see happening inside the upper part of the test tube?

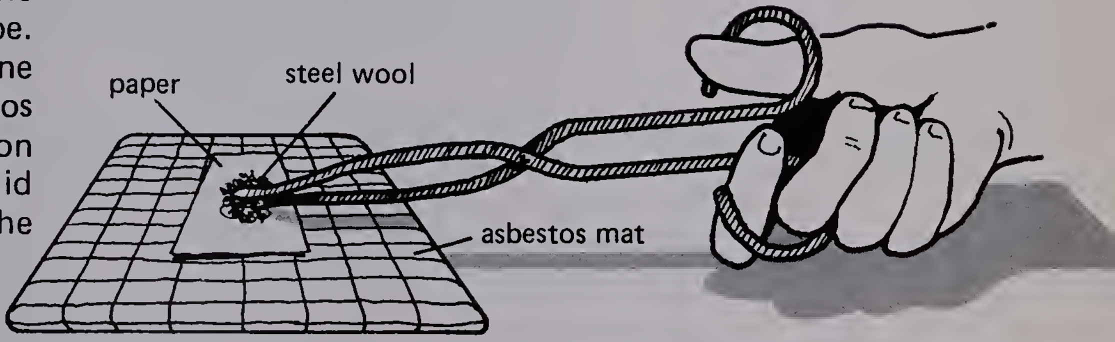
The liquid you see condensing on the inside walls of the test tube is called a *distillate*.

F. Try to get some of the distillate to condense on the steel wool. To do this, you may need to turn the heat up more. Continue to burn off the escaping gases.

G. Turn off the burner. Let the apparatus cool. Then remove the stopper and glass-tubing assembly.



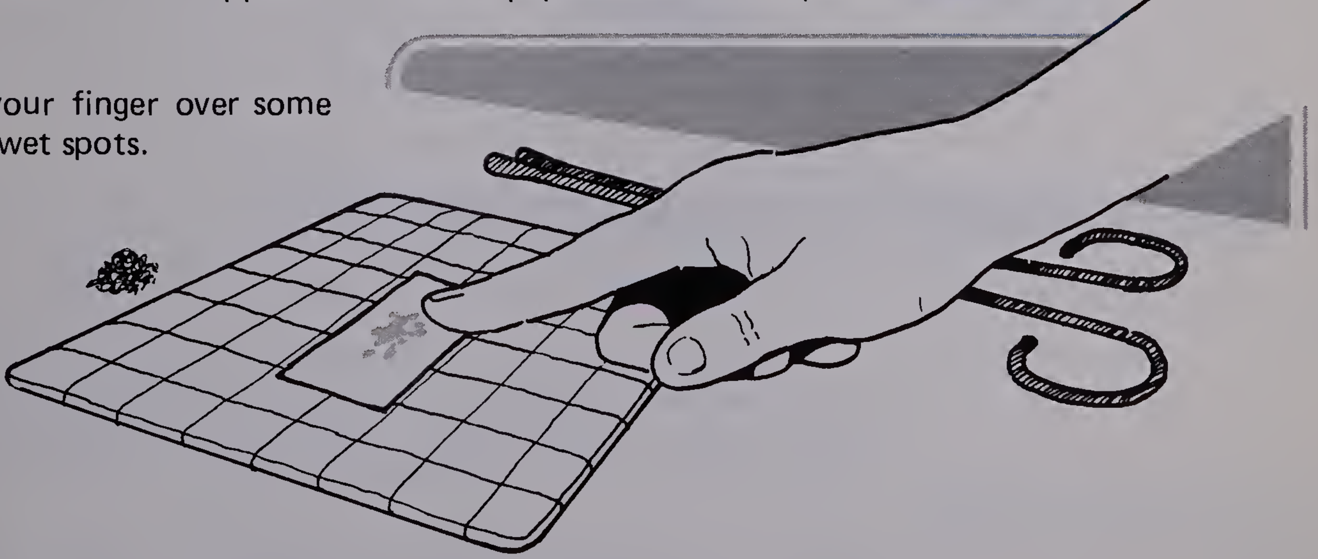
H. With the tongs, take the steel wool out of the test tube. Put the steel wool on one strip of paper on the asbestos pad. Tap the steel wool on the paper so that some liquid gets on the paper. Save the steel wool.



● 17-4. Describe the appearance of the paper where the liquid wet it.

17-4. It looks oily.

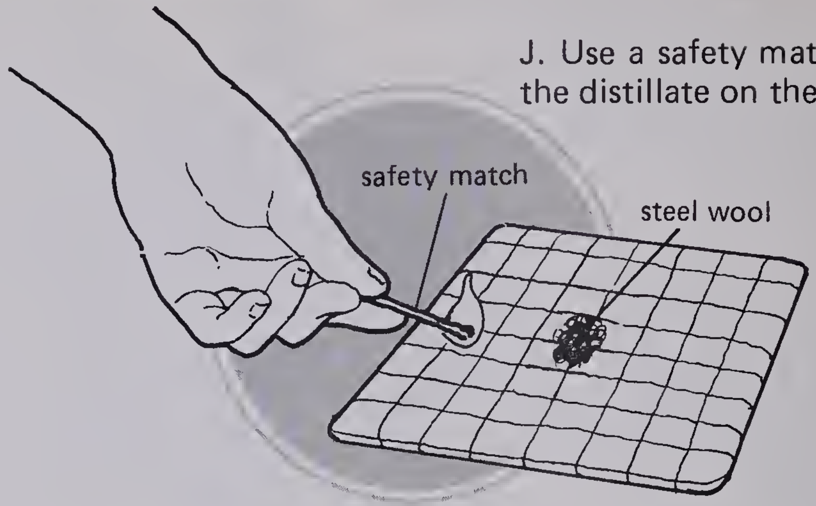
I. Rub your finger over some of those wet spots.



17-5. It has an oily, slippery feeling.

- 17-5. Describe what the distillate feels like.

J. Use a safety match to ignite the distillate on the steel wool.



17-6. The distillate burned with a yellow, smoky flame.

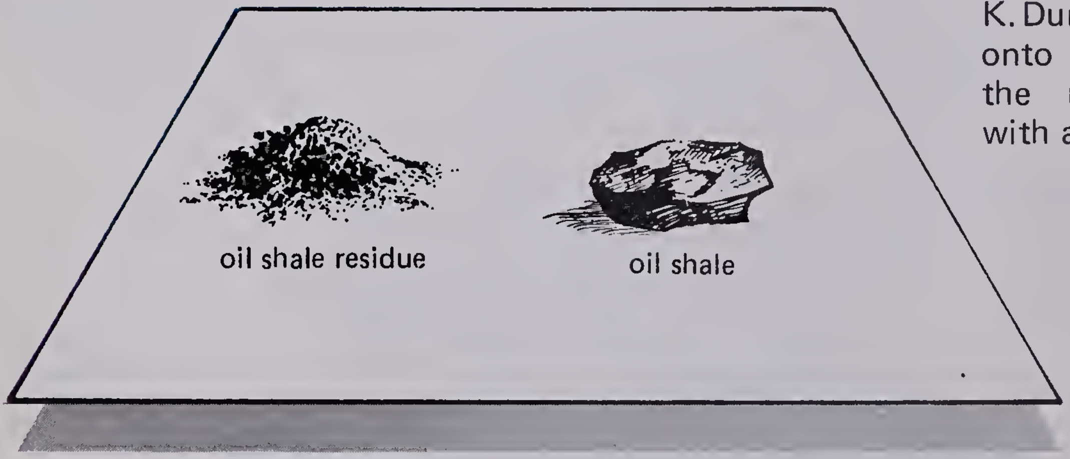
- 17-6. Describe how the distillate on the steel wool burned.

You should have been able to burn both the gases and the liquid that came from the oil shale. In the real process, the gases that come off can be used as fuel for the stronger heating of the crushed oil shale. The liquid can be collected and then processed like crude oil.

17-7. The oil shale is crushed, then heated strongly to form fuel gases and liquids.

- 17-7. Describe how fuel gases and liquids are produced from oil shale.

K. Dump the oil-shale waste onto a piece of paper. Feel the residue. Compare it with a piece of oil shale.



17-8. It is now a crumbly powder.

- 17-8. How has strong heating changed the oil shale?

This change causes the problems described in Activity 8. It's called the "popcorn" effect. Getting fuel gases and liquids from oil shale creates wastes that take up more space than the original rock. So they can't just be put back.

17-9. The oil shale wastes take up more space than the original oil shale.

☆ **17-9. Why is there a problem in disposing of oil shale wastes?**

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ISIS Permanent Staff

Ernest Burkman, Director (1972–)
William R. Snyder, Associate Director (1974–)

Jack J. Bulloff (1977–)
Ace Carroll (1975–)
Maxwell Caskie (1976–)
Robert Celander (1976–)
Richard Chittenden (1976–)
Jerome L. Ciesla (1973–)
Robert L. Cocanougher (1972–)
Sylvia D. Collins (1977–)
Stewart P. Darrow (1973–)
Cheval Fagan (1976–)
Gene Floersch (1975–)
Gail M. Grandy (1973–)
James P. Hale (1974–)
James A. Hathaway (1973–)
Jeanne C. Klinzing (1976–)
John R. Knudstrup (1976–)
Ronald C. Laugen (1973–)
Robert C. Loser (1976–)
Adrian D. Lovell (1972–)
Elisabeth McCurnin (1976–)
Dawn McQueen (1975–)
Marvin D. Patterson (1973–)
Charles E. Peters (1973–)
Ronald J. Polland (1976–)
John Roberge (1976–)
Dee Dee Shand (1974–)
Lois S. Wilson (1973–)
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Former Staff

Tedd Arnold, Gary K. Baker, Denis Blakeway, Calvin E. Bolin, Drennen A. Browne, Robert Buchanan, Marcia Bujold, David L. Camp, Gwendie Camp, Clifton Bob Clark, Sara P. Craig, Julia Damon, Allan D. Dawson, Joel Dawson, Ronald N. Giese, James A. Greenwood, Fred Hartford, Lila T. Kirschbaum, Michael Krone, Francis X. Lawlor, Clarke G. Lieffers, Pam Little, Bernadette R. Menhusen, Brenda Musgrave-Propst, Gerald Neufeld, Hugh Nicholson, Barney Parker, David D. Redfield, Susan Reichman, George A. Reid, Jr., Beverly Smith, Donald A. Smith, John A. Sumner, Clifford Swartz, Jenne Taylor, Mike Tillmans, Ralph G. Vedros, Robert Vickery, Brian Webber, Jay A. Young

Writing Conference Participation and Author Consultants

Betsy Balzano, SUNY at Brockport; David Berey, Roslyn (NY) Schools; Robert Bernoff, Penn. State University; Capt. George Bond, Naval Coastal Systems Laboratory; Ted Bredderman, Delmar, New York; John Cunningham, Keene State College; James DeRose, Marple-Newton (PA) School District; Robert D. Eddy, Tufts University; I. Dwaine Eubanks, Oklahoma State University; Roy Gallant, Rangeley, Maine; Orrin Gould, University of Illinois; Francis U. Hackley, Leon (FL) Schools; Jack Hassard, Georgia State University; Robert E. Horvat, SUNY at Buffalo; Stuart J. Inglis, Medford (OR) School District; Jane Kahle, Purdue University; Al Kaskel, Evanston (IL) Schools; David Klasson, Fall River (CA) Joint Unified School District; David Kuhn, Tarrytown (NY) Schools; Clarence T. Lange, Clayton (MO) Schools; Sander Latts, University of Minnesota; Robert L. Lehrman, Roslyn (NY) Schools; Harleen McAda, University of California at Santa Barbara; Wendell Mohling, Shawnee Mission (KS) Schools; Floyd Monaghan, Michigan State University; Rod O'Connor, Texas A & M University; M. Larry Peck, Texas A & M University; Shirley Richardson, San Diego (CA) Schools; Guenter Schwarz (Deceased); Douglas P. Smith, Florida State University; Claude A. Welch, Macalester College; Owen York, Kenyon College

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